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Willmeroth et al.

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(54) **MOS TRANSISTOR WITH ELEVATED GATE DRAIN CAPACITY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Dec. 22, 2010**

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Related U.S. Application Data

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(51) **Int. Cl.**
H01L 29/66 (2006.01)

(52) **U.S. Cl.**
USPC **257/330**; 257/242; 257/328; 257/329; 257/E29.118; 257/E29.257; 257/E21.419; 438/212; 438/268; 438/270

(58) **Field of Classification Search** 438/212, 438/268, 259, 270, 271, 589; 257/328, 329, 257/330, E21.384, E21.419, E29.257
See application file for complete search history.

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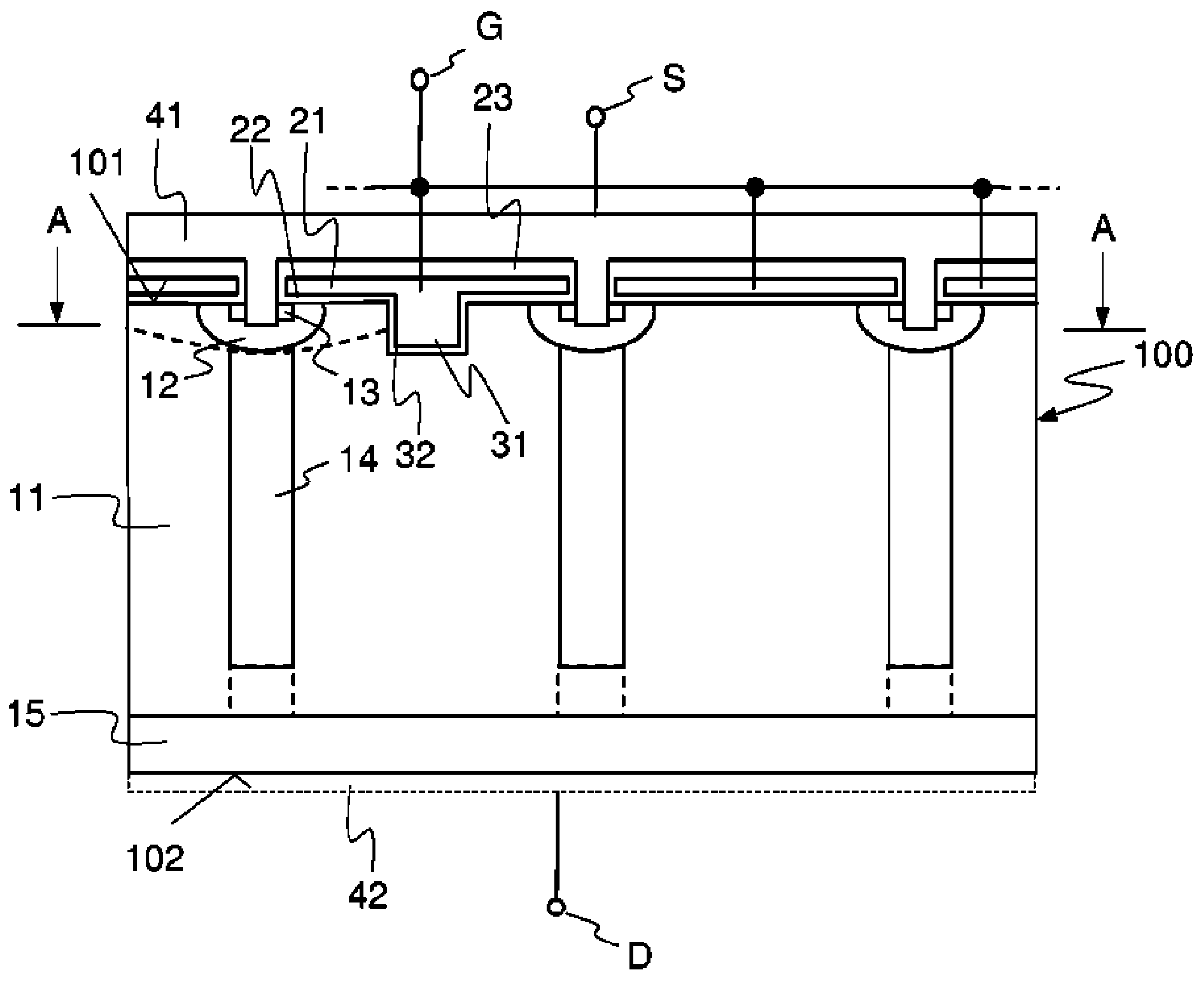
(57) **ABSTRACT**

A MOS transistor having an increased gate-drain capacitance is described. One embodiment provides a drift zone of a first conduction type. At least one transistor cell has a body zone, a source zone separated from the drift zone by the body zone, and a gate electrode, which is arranged adjacent to the body zone and which is dielectrically insulated from the body zone by a gate dielectric. At least one compensation zone of the first conduction type is arranged in the drift zone. At least one feedback electrode is arranged at a distance from the body zone, which is dielectrically insulated from the drift zone by a feedback dielectric and which is electrically conductively connected to the gate electrode.

10 Claims, 9 Drawing Sheets



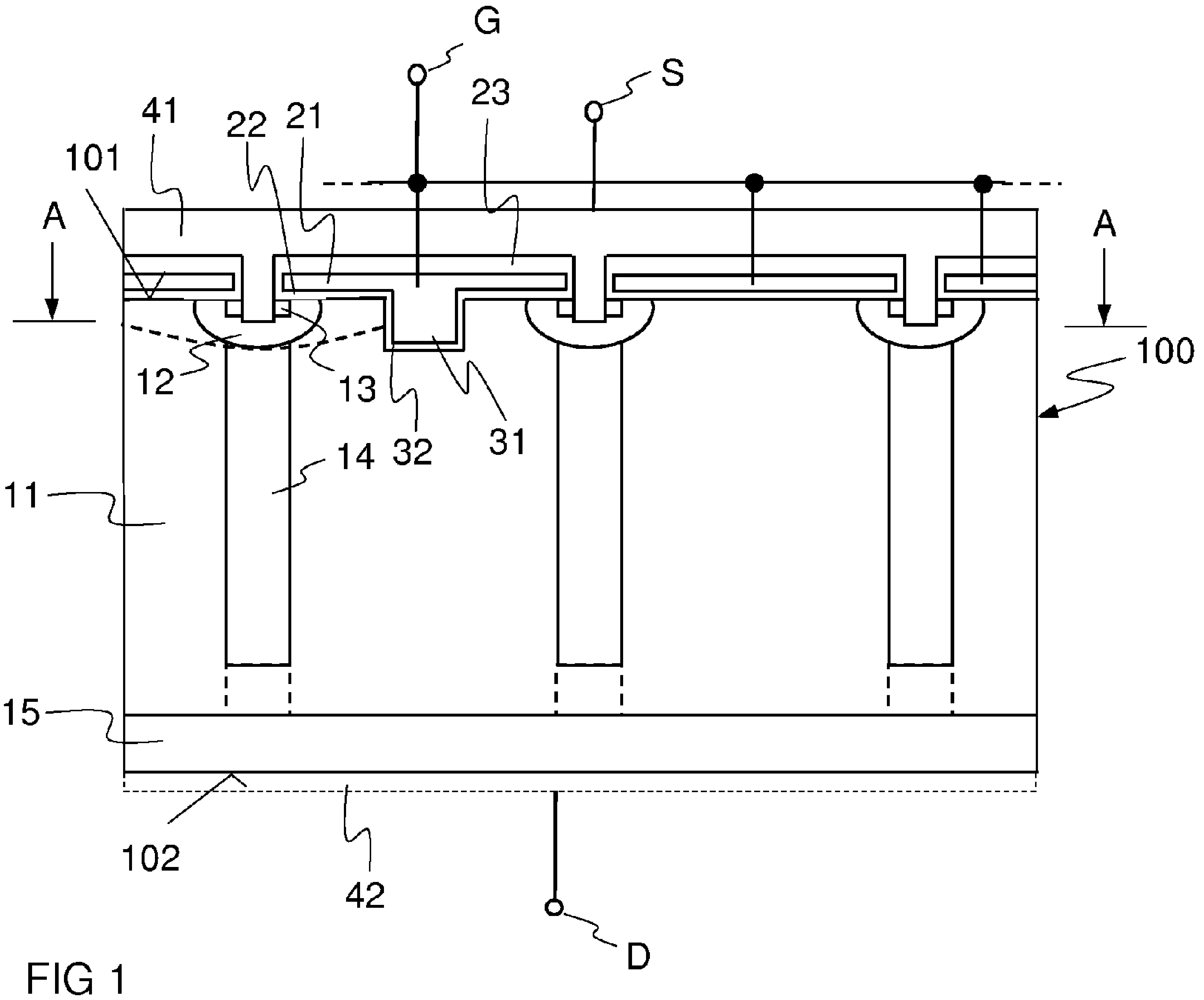


FIG 1

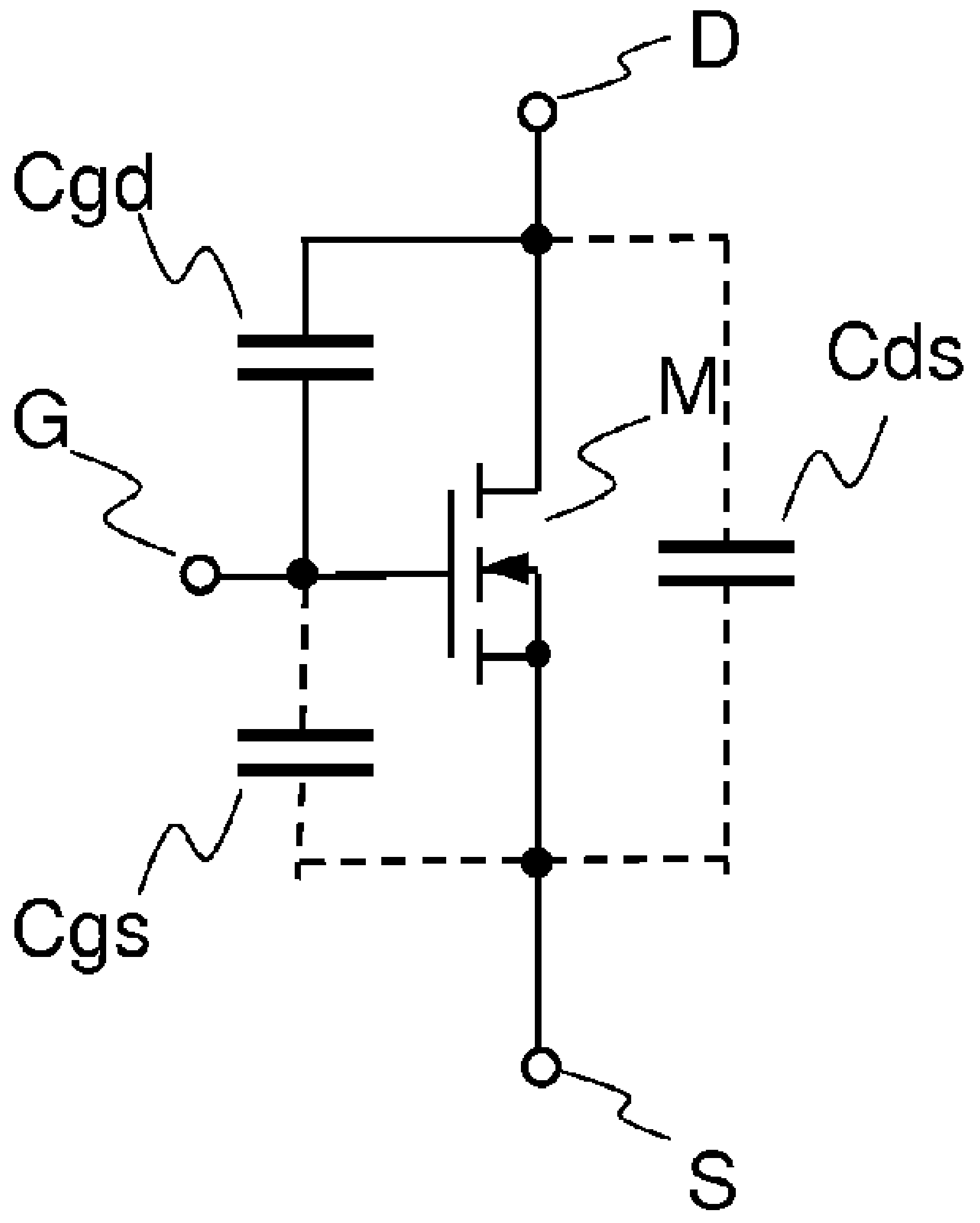


FIG 2

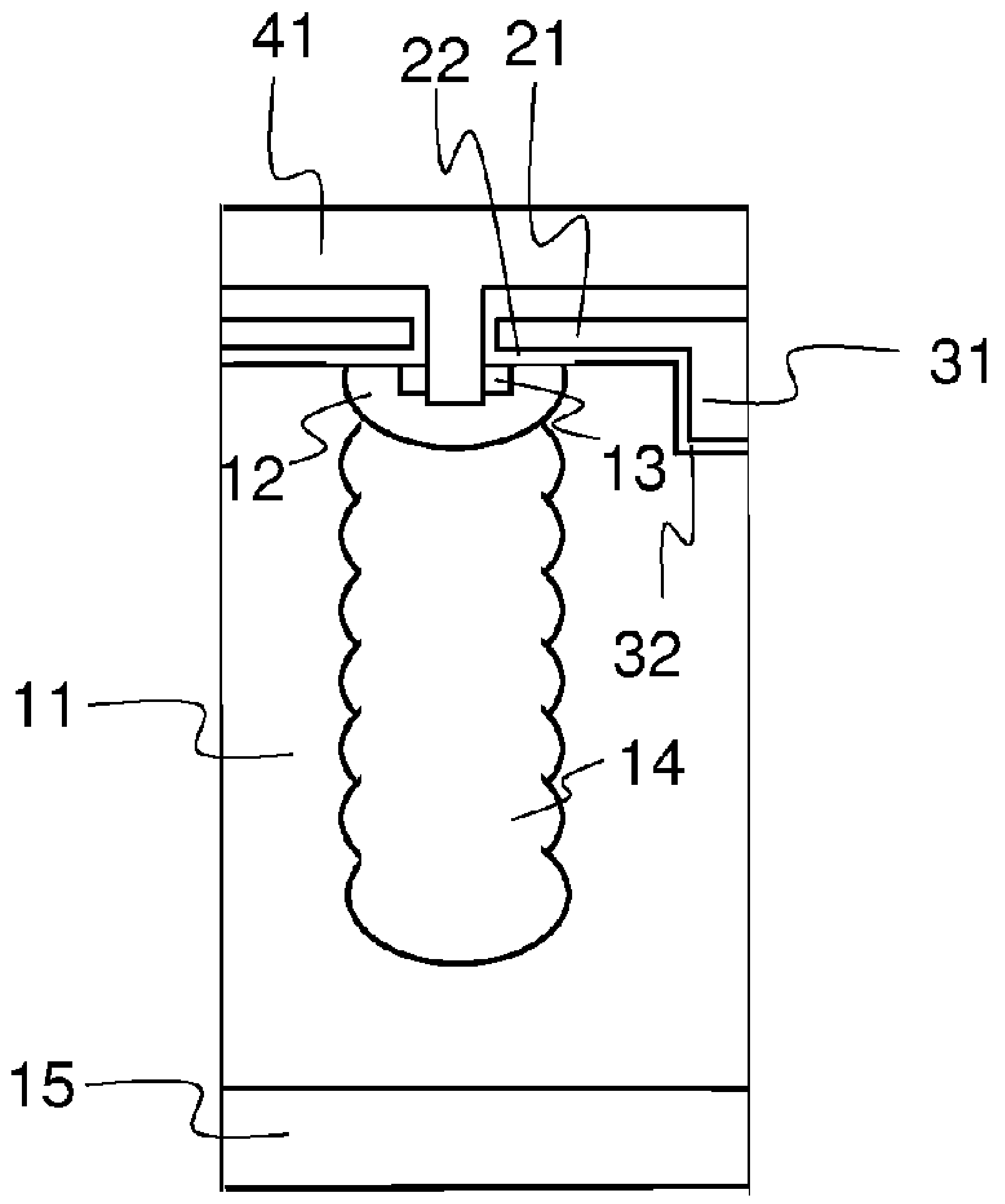


FIG 3

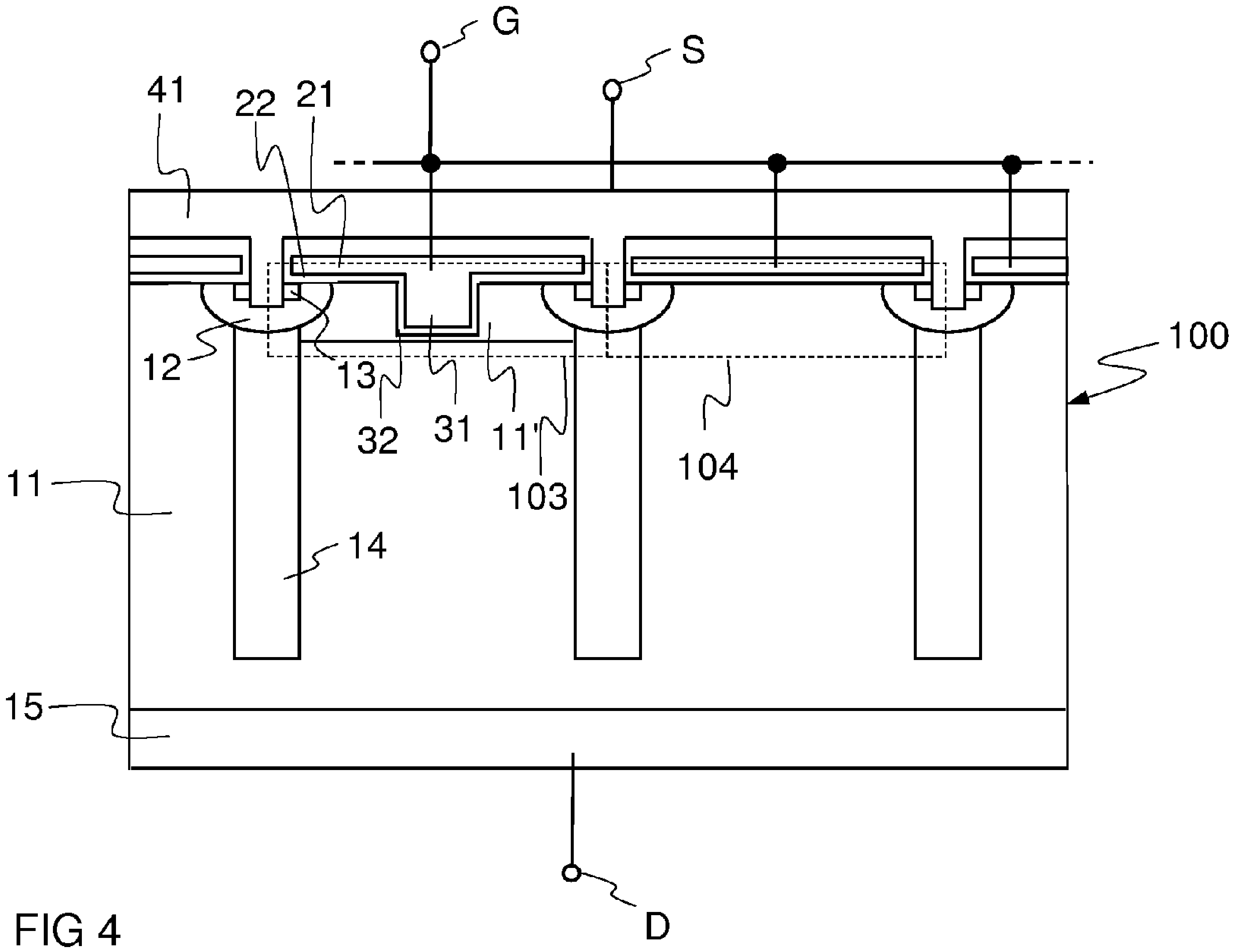

G
S
41
22
21
100
12
13
32
31
11'
103
104
11
14
15
D

FIG 4

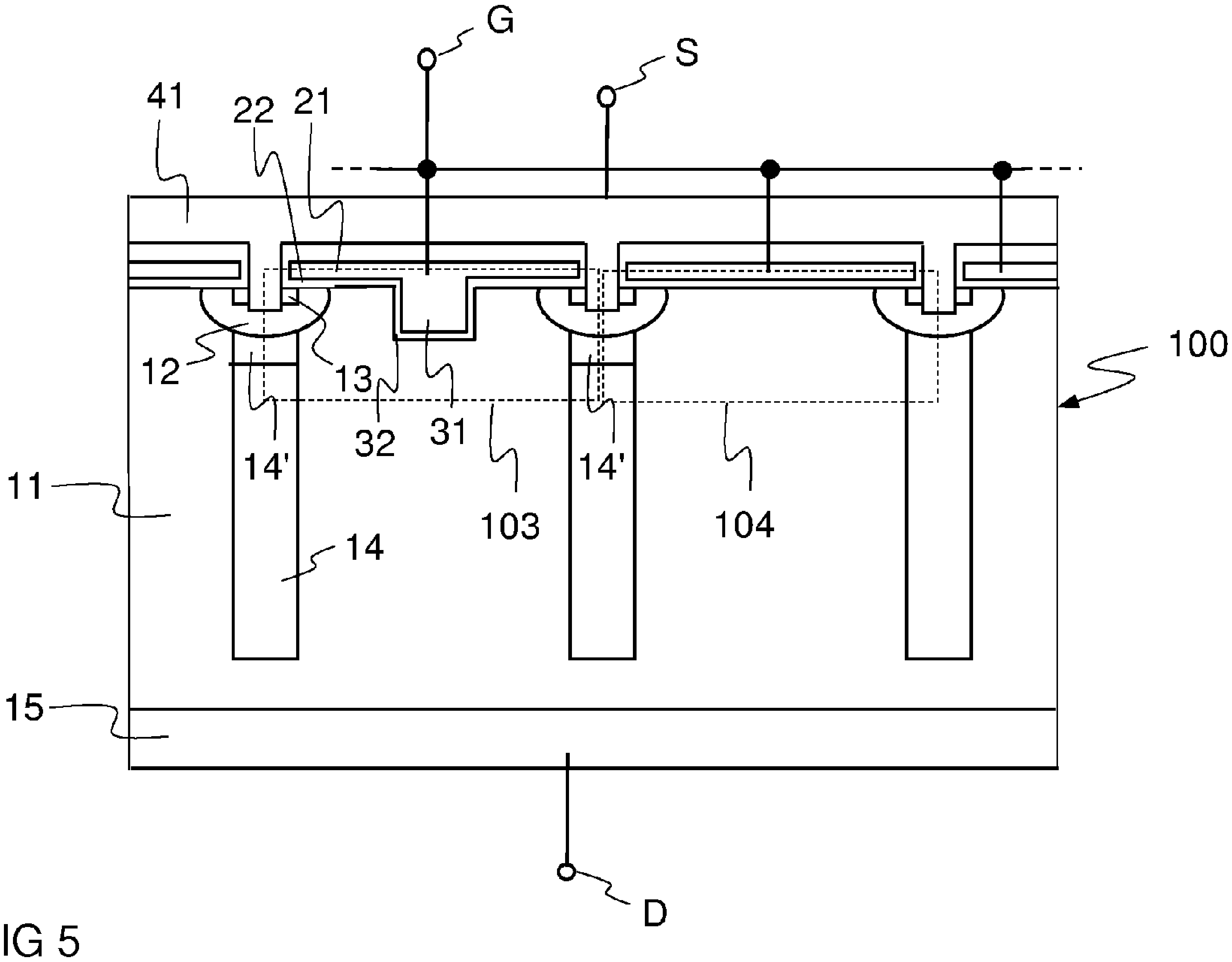

G
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FIG 5

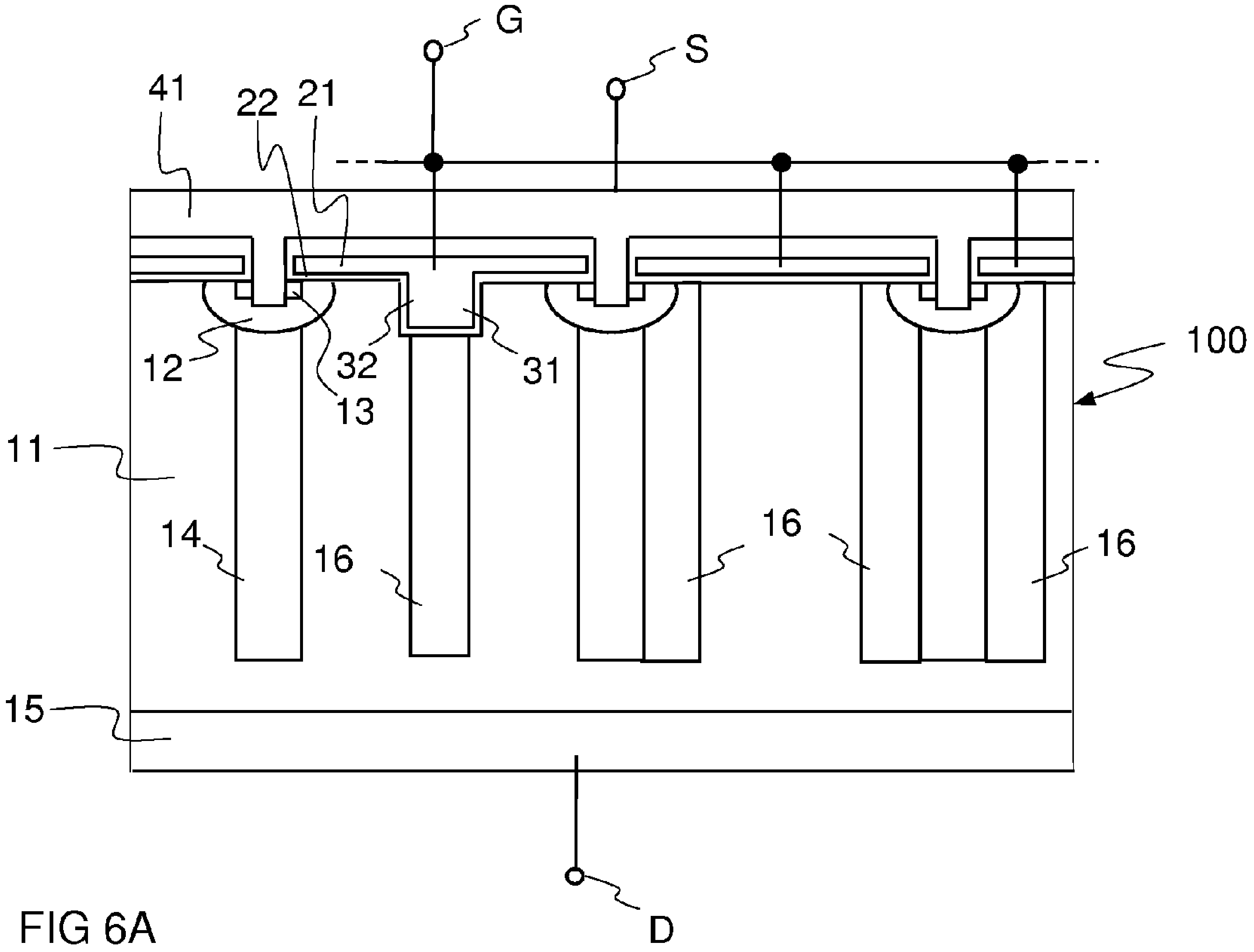
G
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FIG 6A

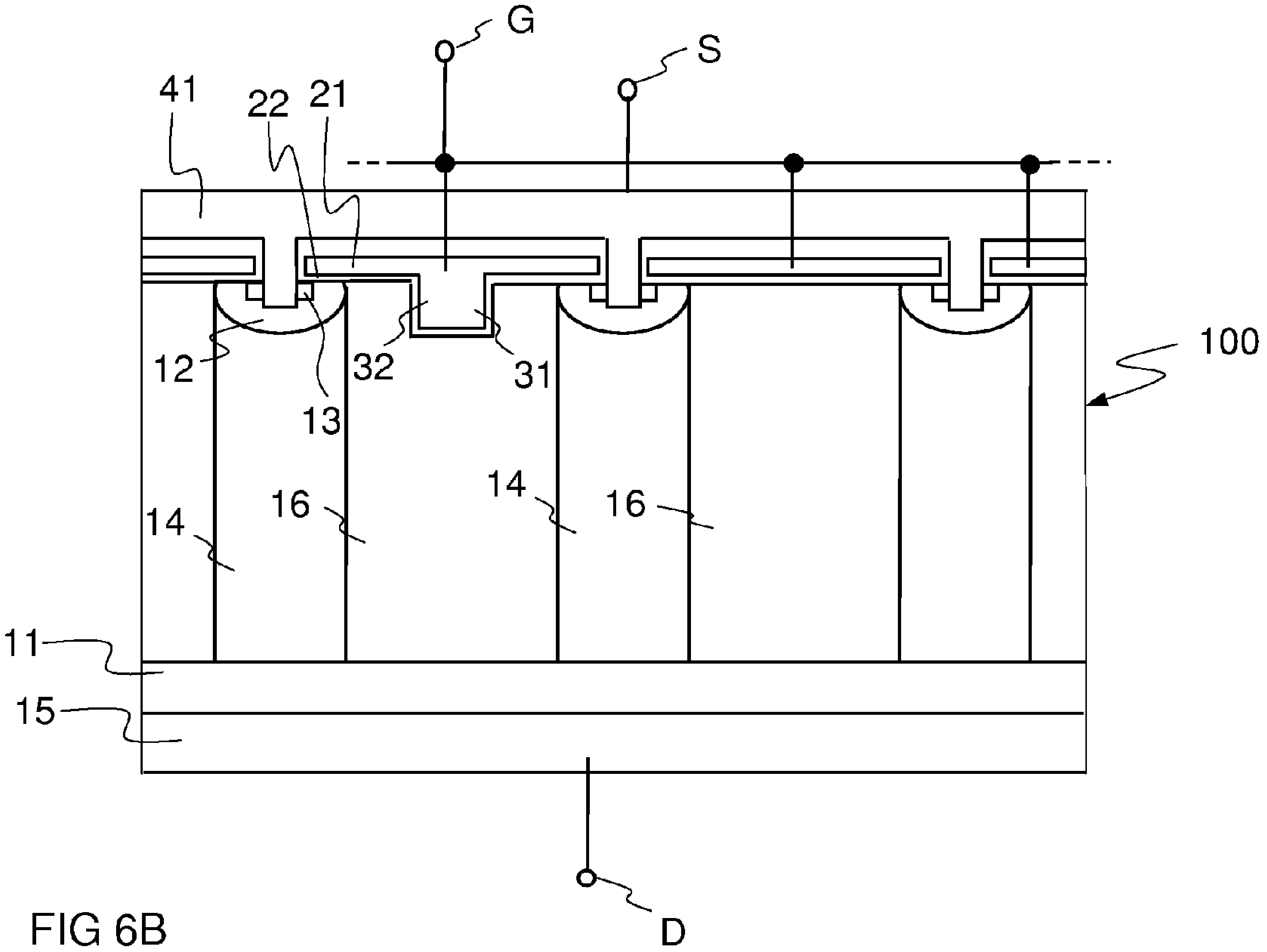
G
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FIG 6B

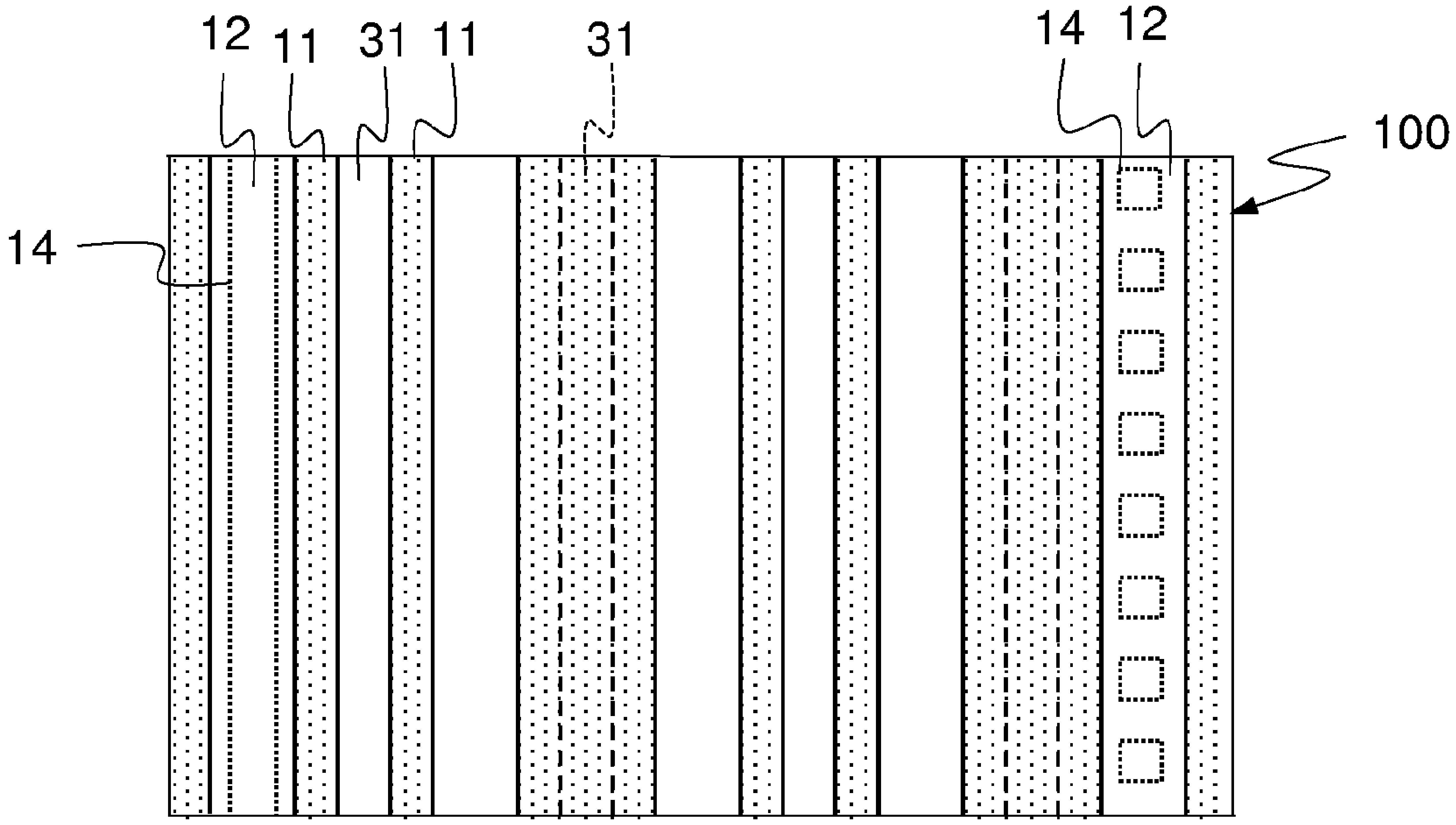

FIG 7

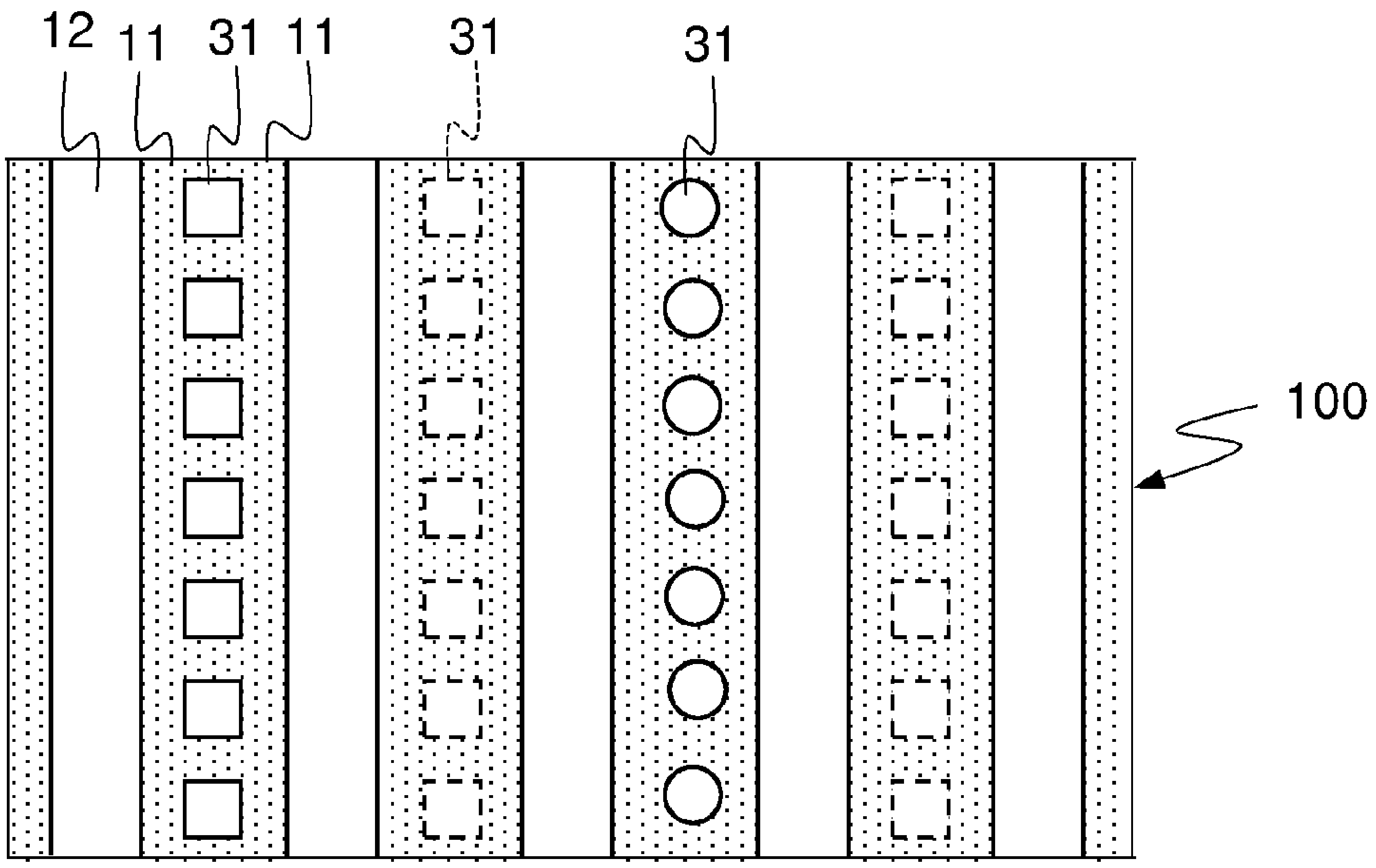

FIG 8

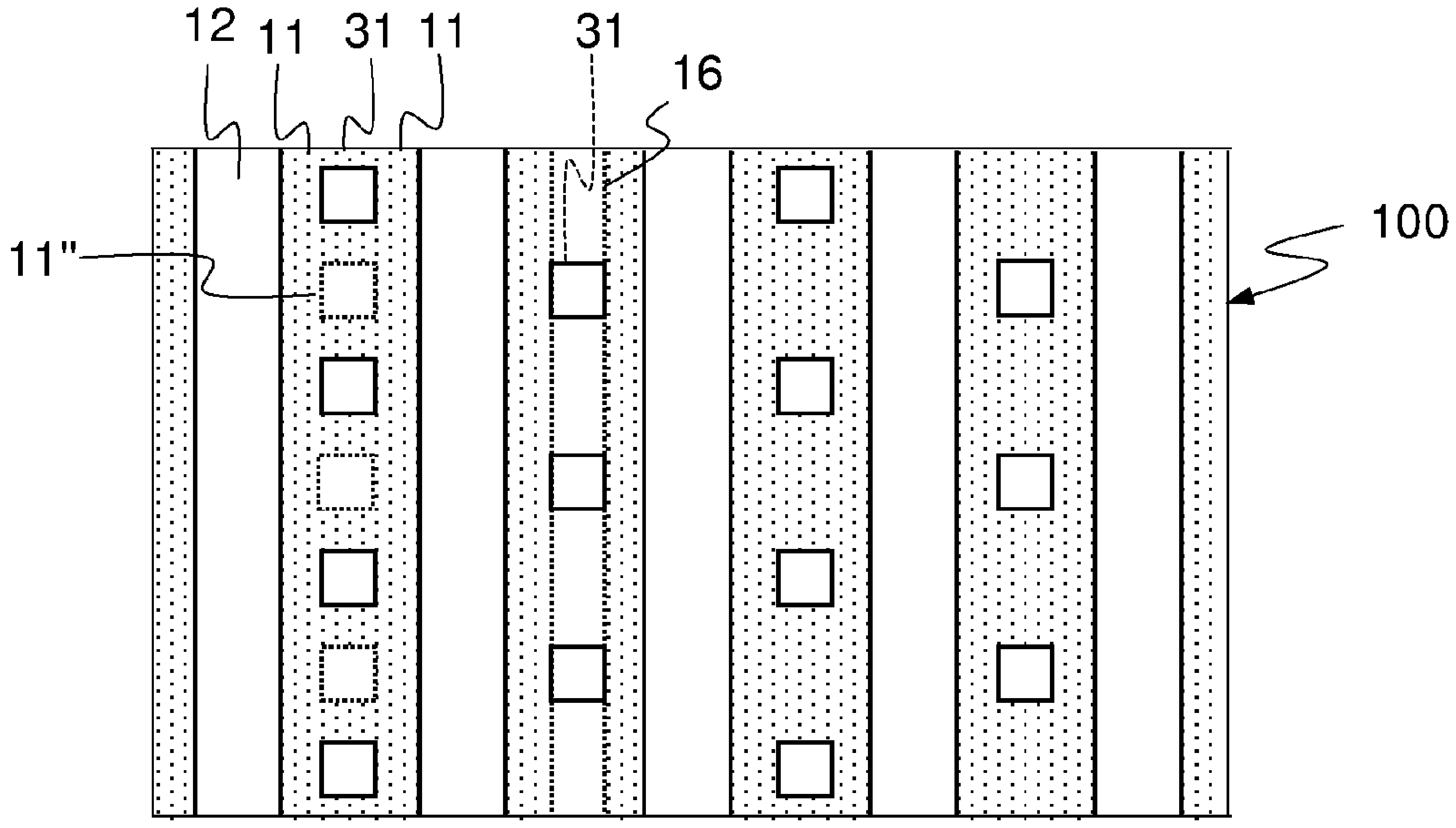

FIG 9

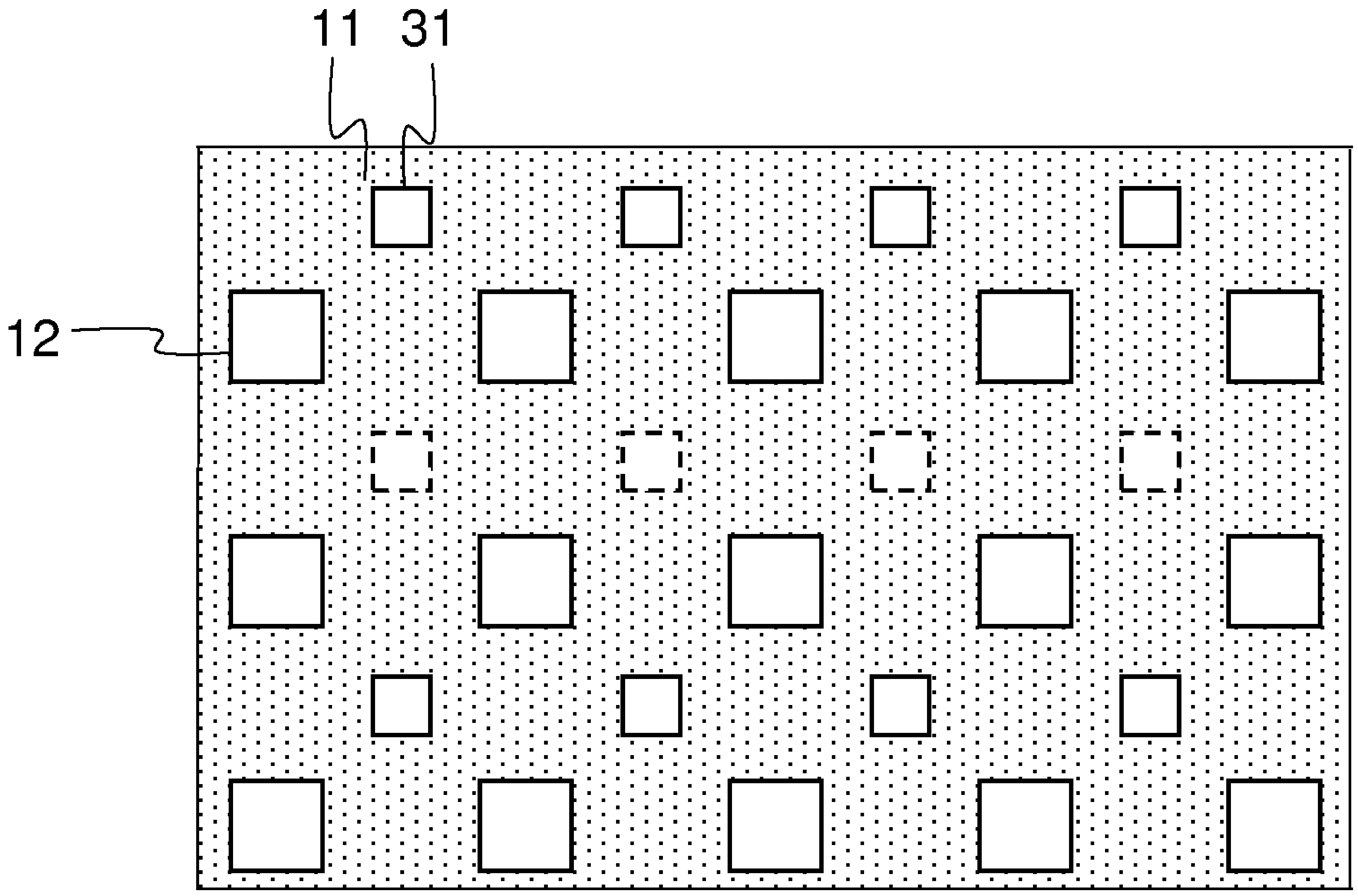

FIG 10

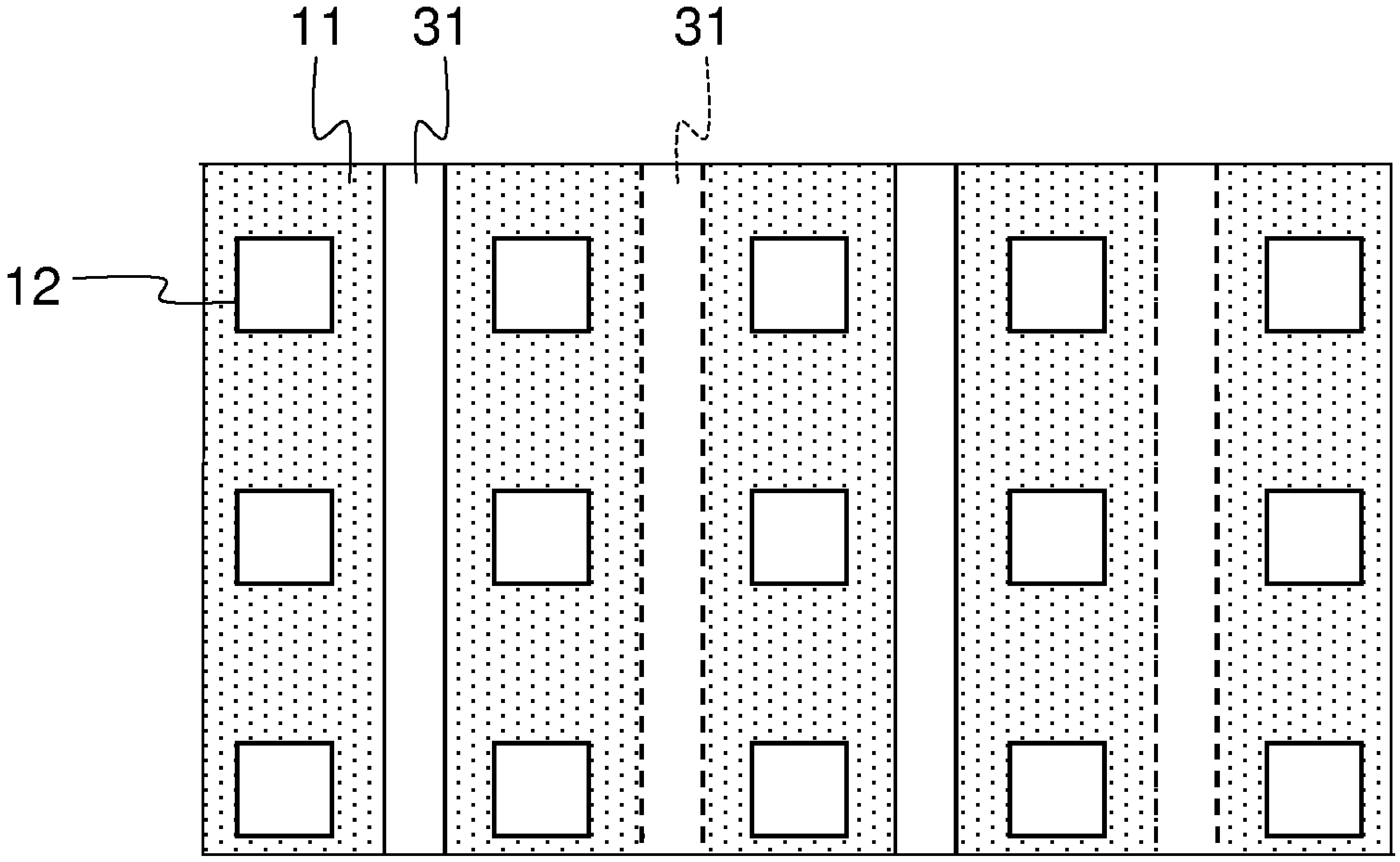

FIG 11

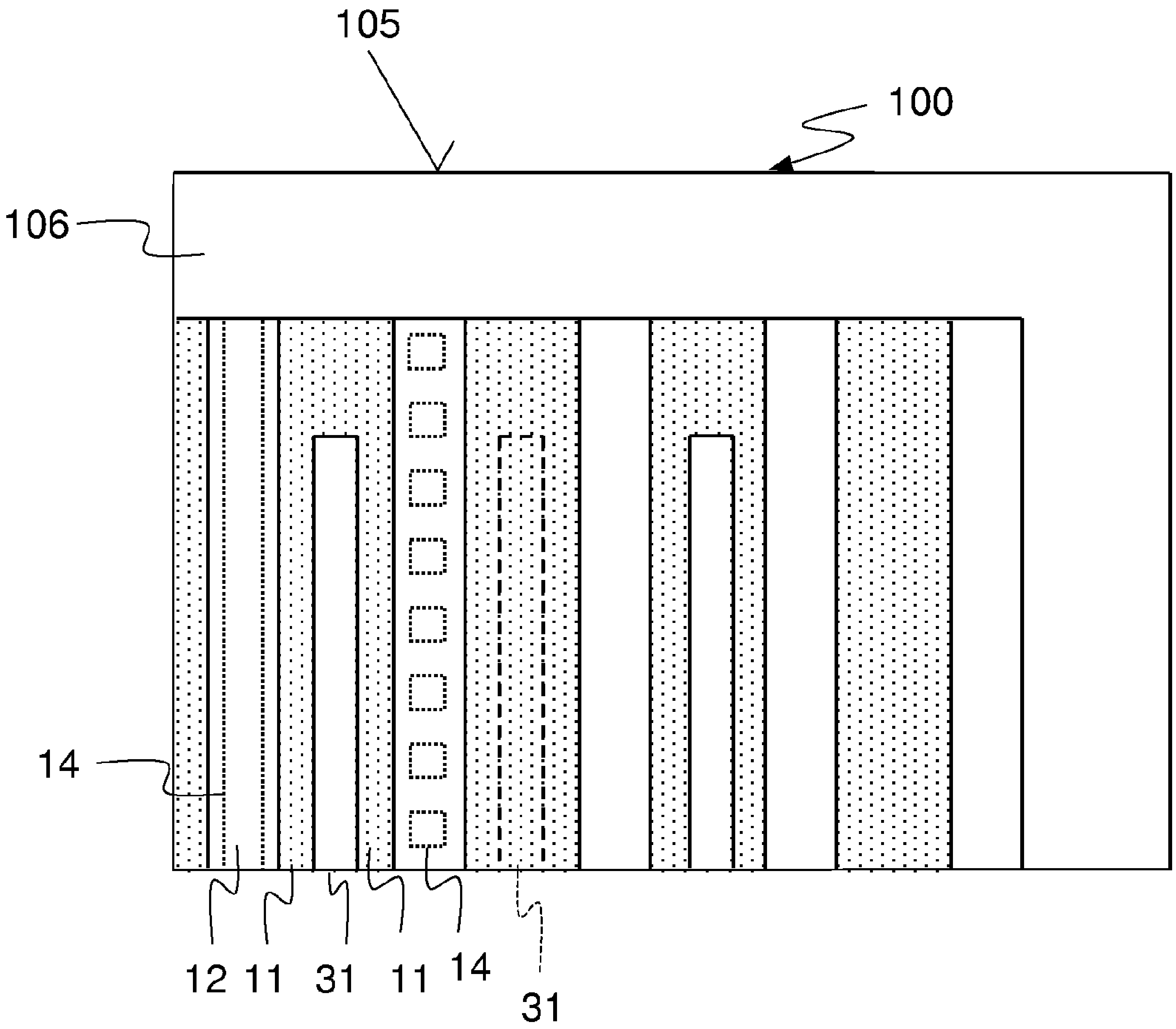

FIG 12

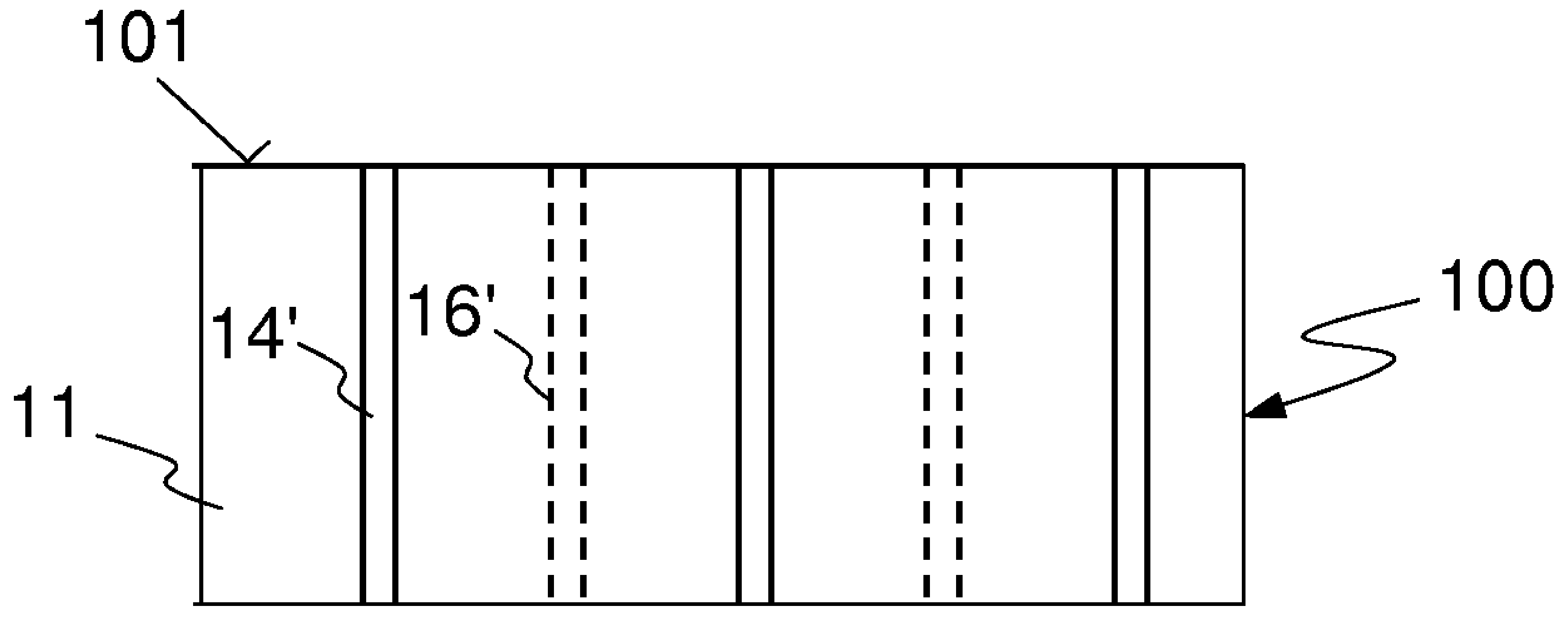

FIG 13A

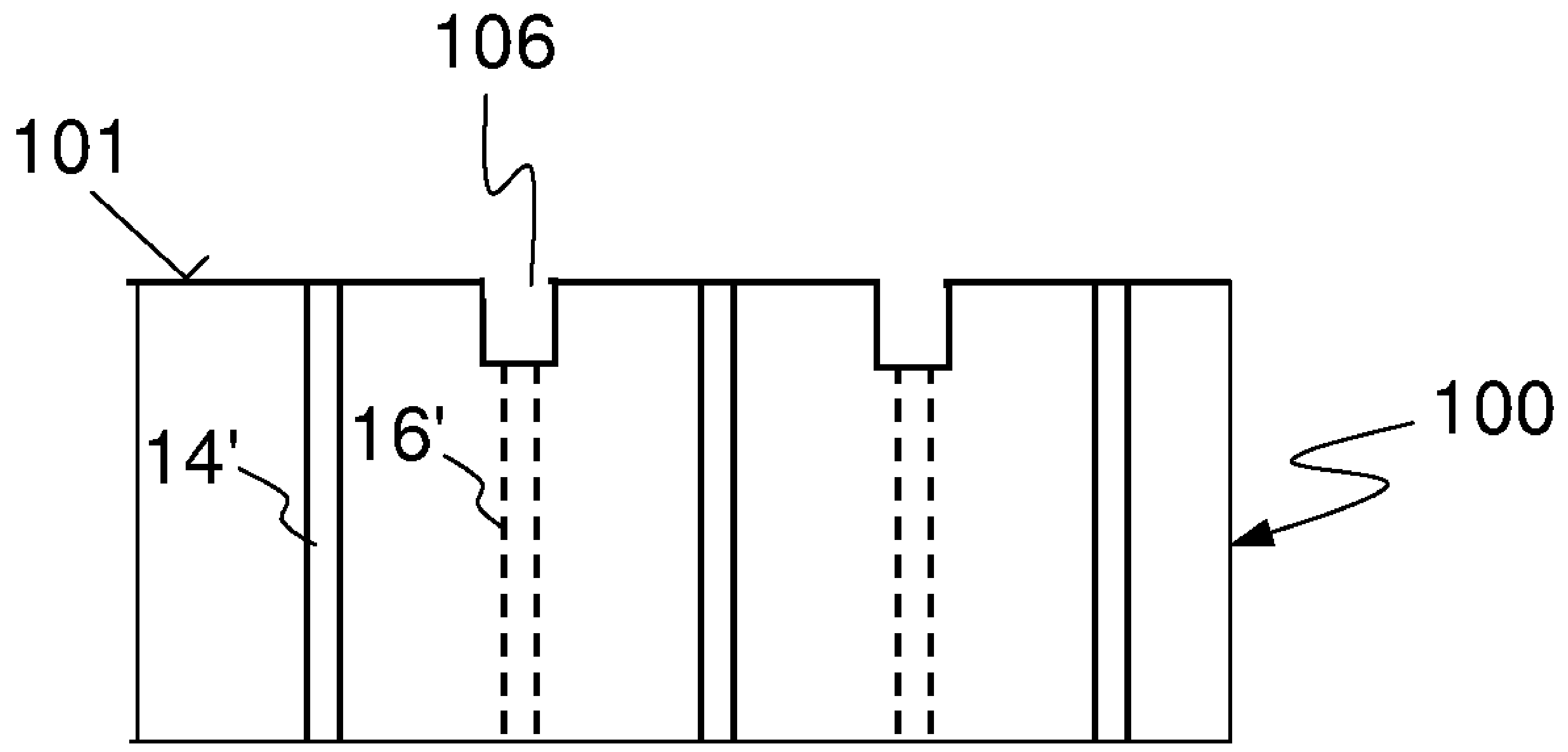

FIG 13B

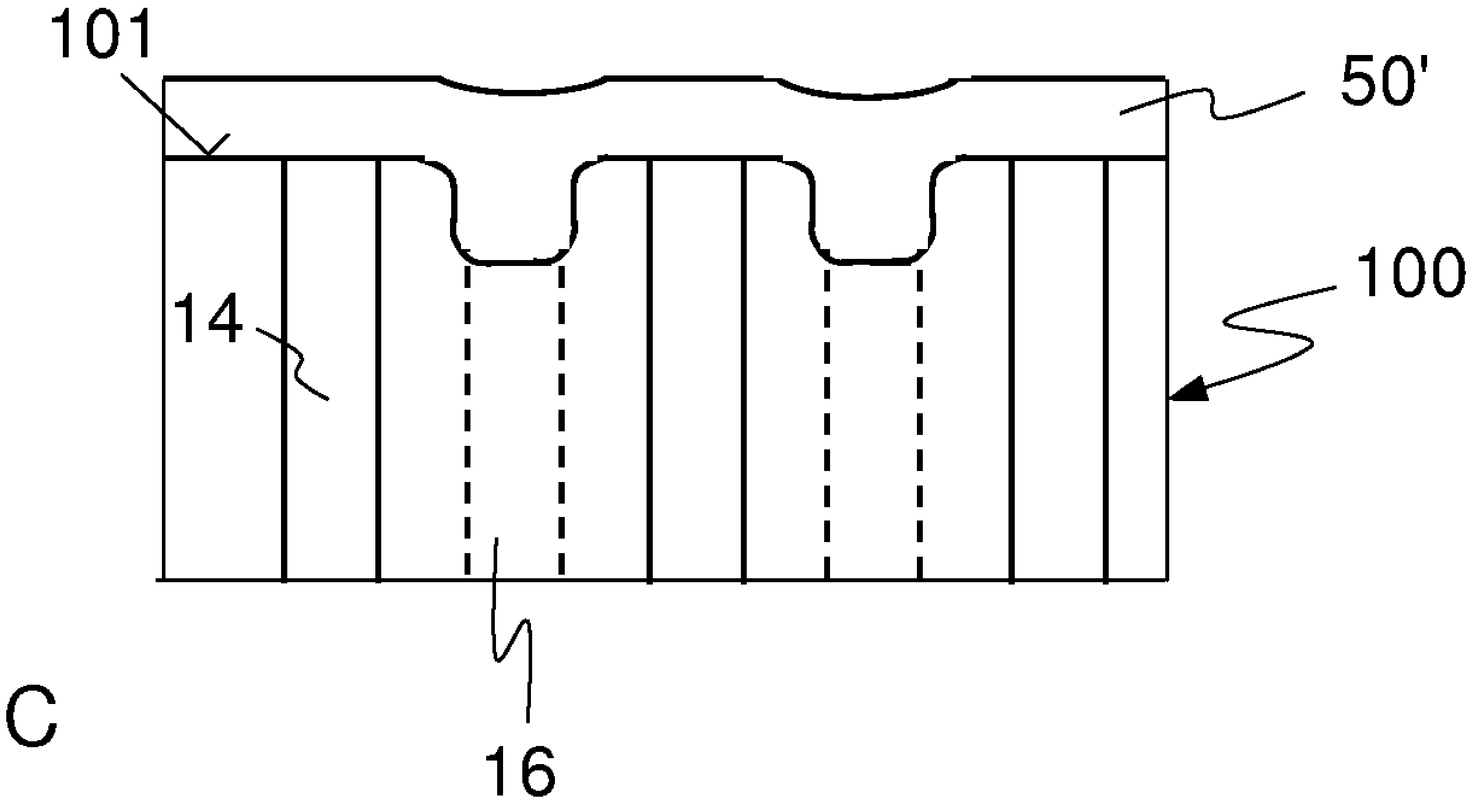

FIG 13C

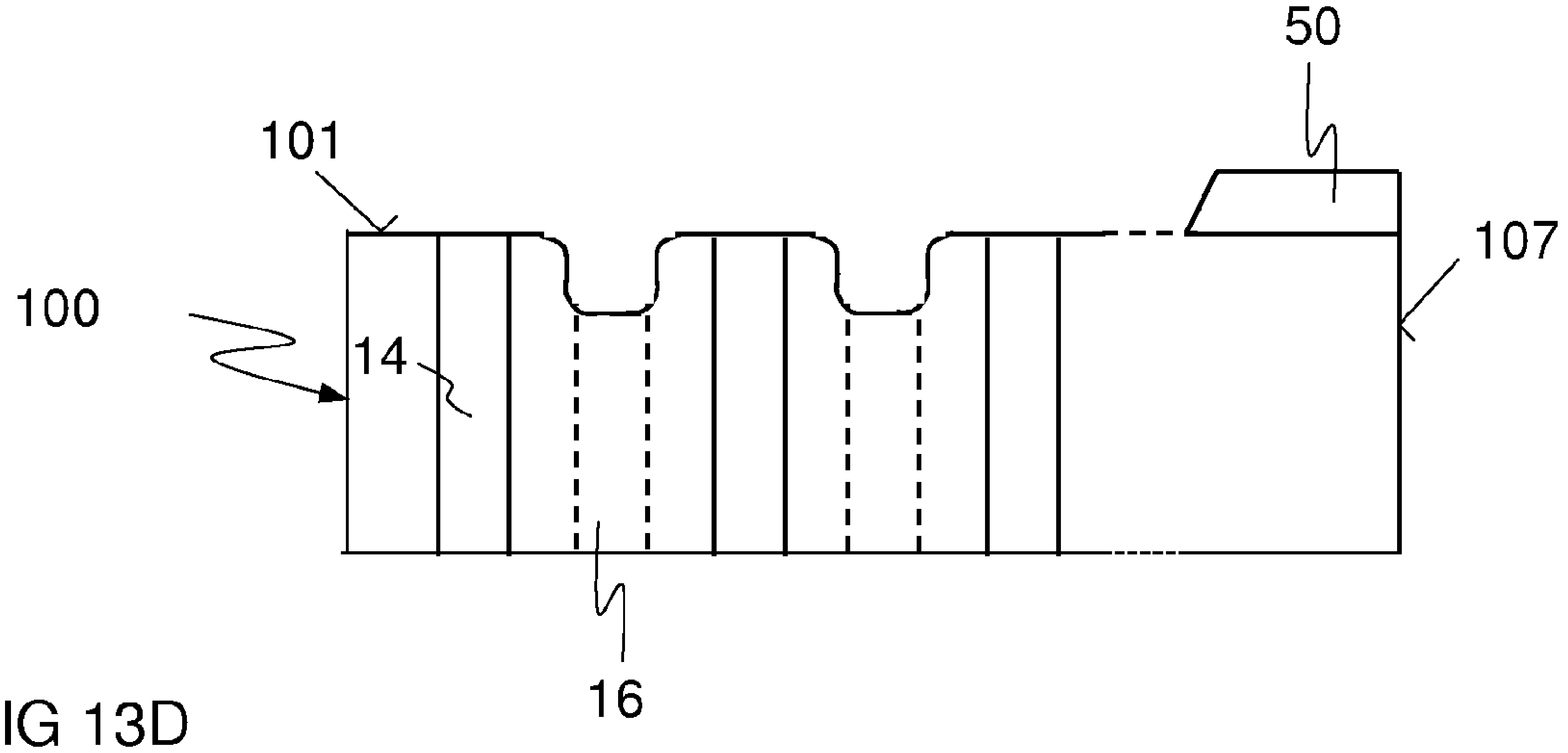

FIG 13D

MOS TRANSISTOR WITH ELEVATED GATE DRAIN CAPACITY

CROSS-REFERENCE TO RELATED APPLICATIONS

This Utility Patent Application is a continuation application of U.S. application Ser. No. 12/241,947, filed Sep. 30, 2008, which is incorporated herein by reference.

BACKGROUND

MOS transistors, such as e.g., MOSFETs or IGBTs, can be used as electronic switches for switching electrical loads. Such MOS transistors suitable for switching electrical loads are also referred to as power MOS transistors. One aim in the development of these MOS transistors is to achieve a lowest possible area-specific on resistance ($R_{ON}\cdot A$) for a given dielectric strength. This area-specific on resistance is the product of the ohmic resistance (R_{ON}) of the transistor in the on state and the chip area (A) required for realizing the transistor.

Power transistors have a drift zone, in which a space charge zone or depletion layer zone can propagate when the component is turned off and a reverse voltage is present, and which in this way takes up the reverse voltage present. In the case of compensation components, a complementarily doped compensation zone is present in the drift zone, wherein the drift zone and the compensation zone are mutually depleted of charge carriers when the component is turned off. The provision of such a compensation zone permits a higher doping of the drift zone for the same dielectric strength. Relative to the on resistivity, this means that the on resistance (R_{ON}) can be reduced with the chip area (A) remaining the same, or that the chip area can be reduced with the on resistance remaining the same.

With reduction of the chip area and the associated reduction of the capacitances contained in the component, the switching behavior of the transistor changes to the effect that the transistor switches more rapidly, that is to say that when suitable drive signals are applied to a gate electrode, the transistor changes more rapidly from the on state to the off state or from the off state to the on state. Rapid switching is tantamount to steep edges of a voltage present across the transistor or the switched load or of a current flowing through the transistor and the load. Both steep voltage edges and steep current edges can be critical with regard to radiated electromagnetic interference. Furthermore, steep current edges in parasitic inductances can lead to high voltage spikes, and steep voltage edges in conjunction with parasitic capacitances can lead to undesirable oscillations.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of embodiments and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and together with the description serve to explain principles of embodiments. Other embodiments and many of the intended advantages of embodiments will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

FIG. **1** illustrates, on the basis of a vertical cross section through a semiconductor body, one embodiment of a MOS transistor having a drift zone, a transistor cell arranged in the drift zone, a compensation zone arranged in the drift zone, and also a feedback electrode arranged in the drift zone.

FIG. **2** illustrates one embodiment of an electrical equivalent circuit diagram of the MOS transistor.

FIG. **3** illustrates one embodiment of a compensation zone modified by comparison with the embodiment in FIG. **1**.

FIG. **4** illustrates one embodiment of a MOS transistor in which an effective doping concentration of the drift zone is locally reduced in the region of the feedback electrode.

FIG. **5** illustrates one embodiment of a MOS transistor in which the compensation zone has a more highly doped section in the region of the feedback electrode.

FIG. **6** illustrates one embodiment of a MOS transistor in which the drift zone has more highly doped and more lightly doped sections, and in which the feedback electrode is arranged in extension of a more highly doped section.

FIG. **7** illustrates on the basis of a horizontal cross section through a semiconductor body, one embodiment of a MOS transistor having strip-type transistor cells.

FIG. **8** illustrates, on the basis of a horizontal cross-section through a semiconductor body, one embodiment of a MOS transistor having strip-type transistor cells.

FIG. **9** illustrates a further example of a MOS transistor having strip-type transistor cells.

FIG. **10** illustrates one embodiment of a MOS transistor having rectangular transistor cells and rectangular feedback electrodes.

FIG. **11** illustrates one embodiment of a MOS transistor having rectangular transistor cells and strip-type feedback electrodes.

FIG. **12** illustrates one embodiment of an edge region of a MOS transistor.

FIG. **13** illustrates one embodiment of a method for producing trenches for feedback electrodes.

DETAILED DESCRIPTION

In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as "top," "bottom," "front," "back," "leading," "trailing," etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

It is to be understood that the features of the various exemplary embodiments described herein may be combined with each other, unless specifically noted otherwise.

One embodiment provides a MOS transistor having a drift zone of a first conduction type; at least one transistor cell having a body zone, a source zone separated from the drift zone by the body zone, and a gate electrode, which is arranged adjacent to the body zone and which is dielectrically insulated from the body zone by a gate dielectric; at least one compensation zone of the first conduction type which is arranged in the drift zone; at least one feedback electrode, which is arranged at a distance from the body zone, which is dielectrically insulated from the drift zone by a feedback dielectric and which is electrically conductively connected to the gate electrode.

FIG. **1** illustrates one embodiment of a MOS transistor. This MOS transistor includes a semiconductor body **100** having a first side **101**, which is referred to hereinafter as front side, and a side **102** remote from the first side **101**, the side **102** being referred to hereinafter as rear side. FIG. **1** illustrates a vertical cross section through this semiconductor body **100**, that is to say a cross section in a sectional plane running perpendicular to the front and rear sides **101**, **102**.

The transistor has a drift zone **11** of a first conduction type arranged in the semiconductor body **100**, and at least one transistor cell. The transistor cell includes a body zone **12**, a source zone **13** arranged in the body zone **12**, the source zone being separated from the drift zone **11** by the body zone **12**. The body zone **12** is, for example, of a second conduction type, which is complementary to the first conduction type of the drift zone **11**, while the source zone **13** is for example of the first conduction type. The MOS transistor is a normally off MOS transistor in this case. The transistor cell additionally includes a gate electrode **21**, which is arranged adjacent to the body zone **12** and which is dielectrically insulated from the body zone **12** by a gate dielectric **22**. The gate electrode **21** serves for controlling a conducting channel—which is an inversion channel in the case of a normally off transistor—in the body zone **12** between the source zone **13** and the drift zone **11**. For this purpose, the gate electrode **21** extends adjacent to the body zone **12** from the source zone **13** as far as a section of the drift zone **11**.

In the example illustrated, the gate electrode **21** is embodied as a planar gate electrode **21** arranged above the front side **101** of the semiconductor body **100**. A transistor cell having such a planar gate electrode is also referred to as a planar transistor cell. In a manner not illustrated in more specific detail there is, of course, also the possibility of realizing the gate electrode with a different geometry, e.g., as a trench electrode, that is to say as a gate electrode arranged in a trench, which electrode extends in a vertical direction through the source zone **13** and the body zone **12** right into the drift zone **11**.

Contact is made with the source zone **13** of the transistor cell by a source electrode **41**, which also makes contact with the body zone **12** in the example illustrated and which therefore short-circuits the source zone **13** and the body zone **12**. The source electrode **41** forms a source connection S of the transistor. The gate electrode **21** forms a gate connection G of the transistor and the drain zone **15** is connected to a drain connection D. The drain connection D can include a metallization **42** applied to the drain zone **15**, the metallization being illustrated by dashed lines in FIG. **1**. The MOS transistor can have a multiplicity of transistor cells of the same type. These transistor cells are connected in parallel by their source zones **13** being jointly connected to the source connection S and by their gate electrodes **21** being jointly connected to the gate connection G. In this case, the drift zone **11** and the drain zone **15** are common to all the transistor cells.

At least one compensation zone **14** doped complementarily with respect to the drift zone **11** is additionally provided in the drift zone **11**. In the example illustrated, the compensation zone is connected to the body zone **12**, but can also be arranged separately or at a distance from the body zone **12**. The compensation zone **14** doped complementarily with respect to the drift zone **11** can—as illustrated—extend in a vertical direction of the semiconductor **100** and can in this case end at a distance from the drain zone **15** within the drift zone **11**, but can—as is illustrated by dashed lines—also extend as far as the drain zone **15**. Doping concentrations of the drift zone **11** and of the compensation zones **14** are coordinated with one another in one embodiment in such a way that these zones **11**, **14** are mutually fully depleted of charge carriers when the component is turned off.

The transistor additionally has a feedback electrode **31**, which is arranged in the drift zone **11** and which is dielectrically insulated from the drift zone **11** by a feedback dielectric **32**. In the example illustrated, the feedback electrode **31** is arranged in a trench extending into the semiconductor body **100** in a vertical direction proceeding from the front side **101**. In this case, the feedback electrode **31** is arranged in a section of the drift zone **11** which extends as far as the front side **101**. The feedback electrode **31** is electrically conductively connected to the gate electrode **21**. In this case—as illustrated in FIG. **1**—the feedback electrode **31** and the gate electrode **21** can be realized integrally as a common electrode. An electrically conductive connection between the feedback electrode **31** and the gate electrode **21** can, of course, also be realized in any other manner desired. In the former case, the feedback electrode **31** can be produced by the same method processes by which the gate electrode **21** is produced. The gate electrode **21** and the feedback electrode **31** are composed, for example, of a doped polycrystalline semiconductor material, such as e.g., polysilicon. The semiconductor body **100** is composed for example of silicon.

The feedback electrode **31** and the feedback dielectric **32** surrounding the feedback electrode **31** can be arranged at a distance from the body zone **12** in a lateral direction of the semiconductor body. In this case, a section of the drift zone **11** is present between the body zone **12** and the feedback dielectric **32**. However, the body zone can also reach as far as the feedback dielectric in a lateral direction, which is illustrated by dashed lines for a transistor cell in the left-hand part of the figure. In this case, the conducting channel (inversion channel), when the component is driven in the on state, extends from the source zone **13** along the gate dielectric **22** and the feedback dielectric **32** right into the drift zone. In this case, too, a threshold voltage of the component is defined at the source-side end of the channel, that is to say in the region in which the gate electrode **21** is arranged.

At a side of the drift zone **11** which is remote from the transistor cell, a drain zone **15** is adjacent to the drift zone **11**. In the case of a transistor embodied as a MOSFET, the drain zone **15** is of the same conduction type as the drift zone **11**, but doped more highly, and, in the case of a MOS transistor embodied as an IGBT, is doped complementarily with respect to the drift zone **11**. In the case of an IGBT, a field stop zone (not illustrated) can be present between the drain zone **15** and the drift zone **11**, the field stop zone being of the same conduction type as the drift zone **11** but doped more highly. The field stop zone can be directly adjacent to the drain zone **15**, but can also be arranged at a distance from the drain zone **15**.

In the case of an n-conducting MOSFET, the drift zone **11** and the source zone **13** are n-doped, while the body zone **12** and the compensation zone **14** are p-doped. In the case of a p-conducting MOSFET, these component zones are correspondingly doped complementarily. The doping concentration of the drift zone **11** lies for example within the range of between 10^{12} cm^{-3} and 10^{17} cm^{-3}, the doping concentration of the body zone **12** lies for example within the range of between 10^{16} cm^{-3} and 10^{18} cm^{-3}, the doping concentration of the source zone **13** lies for example within the range of between 10^{18} cm^{-3} and 10^{20} cm^{-3}, and the doping concentration of the drain zone **15** lies for example within the range of between 10^{17} cm^{-3} and 10^{20} cm^{-3}.

The component illustrated in FIG. **1** is realized as a vertical component, that is to say that a main current flow direction of this component runs in a vertical direction of the semiconductor body. It should be noted in this connection that the drain zone **15** need not necessarily be adjacent to the rear side **102** of the semiconductor body **100**. In a manner not illustrated in more specific detail there is also the possibility of realizing the drain zone **15** as a buried layer within the semiconductor body and of making contact with this drain zone via the front side **101** by a doped connection zone being led from the front side **101** as far as the buried drain zone at the edge of a cell array containing the transistor cell.

The feedback dielectric **32** can—as illustrated—form together with the gate dielectric **22** a continuous dielectric layer, and that is to say that the feedback dielectric **32** and the gate dielectric can be identical with regard to the material composition and the thickness. In this case, the feedback dielectric **32** can be produced by the same method processes by which the gate dialectic **22** is produced.

FIG. **2** illustrates the electrical equivalent circuit diagram of the MOS transistor illustrated in FIG. **1**. For explanation purposes it shall be assumed that this MOS transistor is a normally off n-conducting MOSFET. However, the explanations below are correspondingly applicable to other MOS transistors as well. The equivalent circuit diagram illustrates not only the actual transistor M but also its gate-source capacitance Cgs, which is present between the gate connection G and the source connection S, its gate-drain capacitance Cgd, which is also referred to as feedback capacitance and which is present between the gate connection G and the drain connection D, and also its drain-source capacitance Cds, which is present between the drain connection D and the source connection S. The switching behavior of the MOS transistor is dependent on these capacitances Cgs, Cgd, Cds. In the case of the component illustrated in FIG. **1**, the feedback capacitance Cgd is enlarged in a targeted manner by providing the feedback electrode **31**. This is because the feedback electrode **31** connected to the gate electrode **21** forms, together with the feedback dielectric **32** and the drift zone **11**, a capacitance between the gate connection G and the drain connection D of the component. A change in the gate-drain capacitance is also accompanied by a change in the output capacitance Coss of the component, which corresponds to the sum of the gate-drain capacitance Cgd and the drain-source capacitance. The gate-source capacitance Cgs is not influenced by the feedback electrode. The gate-source capacitance Cgs and the drain-source capacitance Cds are not considered in any further detail below and are therefore illustrated by dashed lines in FIG. **2**.

By enlarging the feedback electrode Cgd, the switching speed of the MOS transistor can be slowed down with otherwise identical component properties, that is to say with identical doping relations, with an identical number of transistor cells, with an identical gate-source capacitance Cgs, with an identical output capacitance Coss, etc. the feedback capacitance Cgd has to be subjected to charge reversal during each switching operation of the transistor, that is to say during each transition from the on state to the off state and from the off state to the on state. For a given charging current flowing onto the gate electrode G in the case of driving in the on state and for a given discharge current flowing from the gate electrode G in the case of driving in the off state, this charge-reversal operation lasts all the longer, the larger the gate-drain capacitance Cgd.

The feedback capacitance Cgd of the MOS transistor can be set in a targeted manner by using the number of feedback electrodes **31** provided, and also by using the dimensions thereof in horizontal and vertical directions. For the rest, the component behaves like a conventional MOS transistor and is turned on if an electrical potential suitable for forming a conducting channel in the body zone **12** between the source zone **13** and the drift zone **11** is present at the gate electrode G, and is turned off if such an electrical potential suitable for forming a conducting channel is not present at the gate electrode **21**.

The compensation zone **14** is schematically illustrated in FIG. **1** as a pillar extending in a vertical direction of the semiconductor body **100**. It should be noted that the compensation zone **14** need not necessarily have the geometry of a straight pillar, and that a pn-junction in-between this compensation zone **14** and the surrounding drift zone **11** can have any desired geometry. FIG. **3** illustrates one embodiment of a compensation zone **14** in which a pn-junction between the compensation zone **14** and the drift zone **11** does not form a planar area. The compensation zone **14** illustrated in FIG. **3** can be effected for example by a plurality of successive implantation and/or diffusion processes during epitaxial production of the drift zone **11**.

When the component is turned off, that is to say when a voltage is present between the drain connection D and the source connection S but an electrical potential suitable for forming a conducting channel in the body zone **12** is not present at the gate electrode G, a space charge zone propagates proceeding from the pn-junctions between the body zone **12** and compensation zone **14**, on the one hand, and the drift zone **11**, on the other hand. An electric field accompanying the space charge zone can have field spikes in the region of the feedback electrode **31** or of the feedback dielectric **32** unless additional measures are taken.

Such a field boosting can arise as a result of the fact that when the component is turned off, the feedback electrode **31** is at a lower electrical potential than the surrounding regions of the drift zone **11**, such that a space charge zone propagates in the drift zone **11** proceeding from the feedback dielectric **32**. In order to avoid such field increases or field spikes in the region of the feedback electrode **31**, in one example provision is made for locally altering the degree of compensation in a region of the semiconductor body in which the feedback electrode **31** is arranged, to be precise in favor of charge carriers of the conduction type of the body zone **12** or of the compensation zone **14**. The degree of compensation of the component in the region into which the feedback electrode **31** is arranged is dependent on a ratio of the dopant charges in the region, of the drift zone **11**, in which the feedback electrode **31** is arranged and the dopant charges in those regions of the body zone **12** and of the compensation zone **14** which are adjacent to this section of the drift zone **11** in a lateral direction.

Referring to FIG. **4**, in one example provision is made for the drift zone **11** to be more lightly doped in a section **11'** in which the feedback electrode **31** is arranged than in remaining regions of the drift zone **11**. Such a local reduction of the doping concentration of the drift zone **11** can be achieved, for example, by virtue of the fact that during the method for producing the semiconductor component, dopant atoms of a conduction type complementary to the conduction type of the drift zone **11** are implanted and/or indiffused into the section **11'** of the drift zone, which results in a reduction of the effective doping concentration in the section **11'** of the drift zone **11**. For further explanation, consideration shall be given to a section **103** of the semiconductor body **100** which includes the section of the drift zone **11** in which the feedback electrode **31** is arranged and also sections of the body zone **12** and of the compensation zone **14** which adjoins the section in a lateral direction. The degree of compensation for this section **103** of the semiconductor body is defined as

$$k = \frac{D - A}{D}. \quad (1)$$

In this case, D denotes the number of dopant atoms of the first conduction type, that is to say of the conduction type of the drift zone **11** in this section **103** of the semiconductor body, and A denotes the number of dopant atoms of the second conduction type, that is to say of the conduction type of the body zone **12** and of the compensation zone **14**, in this section **103** of the semiconductor body **100**. A local shift in the degree of compensation in favor of dopant atoms of the second conduction type means that more dopant atoms of the second conduction type are present in this section **103** than in a comparative section **104**. The comparative section **104** is identical to the section **103** with regard to its dimensions and with regard to the dimensions of the sections of the body zone **12**, of the compensation zone **14** and of the drift zone **11** that are contained in it, but differs in that no feedback electrode **31** is present in the section **104**. This comparative section **104** accordingly does not contain a section **11'** of the drift zone **11** in which the doping concentration is locally reduced.

FIG. **5** illustrates a further embodiment for locally changing the degree of compensation. In this example, provision is made for the compensation zone **14** to be doped more highly in sections in those regions which are adjacent to a drift zone section in which the feedback electrode **31** is arranged. In FIG. **5**, the reference symbol **14** designates such a more highly doped section of the compensation zone which is doped more highly than remaining sections of the compensation zone **14**. In the example illustrated, this more highly doped section **14'** of the compensation zone is directly adjacent to the body zone **12**, but can also reach right into the body zone **12** (not illustrated).

Referring to FIG. **6**A, in a further embodiment of the MOS transistor, the drift zone **11** has doped drift zone sections **16** which are of the same conduction type as remaining sections of the drift zone **11** but are doped more highly. These more highly doped drift zone sections **16** run, at least in sections, parallel to the compensation zones **14** and can be arranged at a distance from the compensation zones **14** in a lateral direction, but can also be directly adjacent to the body zones **14**. The right-hand part of FIG. **6**A illustrates an example in which the more highly doped drift zone sections **16** are directly adjacent to the compensation zones **14**. In this case, the more highly doped drift zone sections **16** can be arranged in such a way that the inversion channels that form in the body zones **12** when the component is turned on run into the more highly doped drift zone sections **16**.

Referring to FIG. **6**B, in a further embodiment, the more highly doped drift zone sections **16** and the compensation zones **14** are arranged in such a way that they alternate in a horizontal direction of the semiconductor body **100**. In this case, a more lightly doped drift zone section **11** is only present in a section adjoining the drain zone **15**.

In those regions of the MOS transistor in which a feedback electrode **31** is arranged, the feedback electrode **31** is arranged directly in extension of the more highly doped drift zone section **16**. In this case, more highly doped drift zone sections **11'** which are not arranged adjacent to a feedback electrode **31** extend further in a direction of the front side **101** where the more highly doped drift zone **11'** which are arranged adjacent to a feedback electrode **31**. This automatically results in a local variation of the degree of compensation in favor of dopant atoms of the conduction type of the body zone **12** and of the compensation zone **14** in those regions of the component in which a feedback electrode **31** is arranged.

The individual transistor cells of the MOS transistor can have any desired transistor cell geometry. Furthermore, the feedback electrodes **31** can be assigned to individual transistor cells in principle completely as desired. In other words: the ratio between a number of transistor cells and a number of feedback electrodes present in the component can be chosen completely as desired in order thereby to set the feedback capacitance (Cgd in FIG. **2**) to a desired value. Moreover, the geometry of the transistor cells can be independent of the geometry of the feedback electrodes.

FIG. **7** illustrates one embodiment of a MOS transistor having strip-type transistor cells, on the basis of a horizontal cross section through the semiconductor body **100**. FIG. **7** illustrates a cross section of the component in a sectional plane A-A that is illustrated in FIG. **1** and runs below the source zone **13** through the body zones **12**. Source zones of the individual transistor cells are therefore not illustrated in FIG. **7**. The compensation zones **14** arranged below the body zones **12** are illustrated by dotted liens for individual transistor cells in FIG. **7**.

In the case of the component illustrated in FIG. **7**, the body zones **12**—and accordingly the source zones **13** not illustrated—form elongated strips in a horizontal direction of the semiconductor body **100**. Referring to FIG. **7**, the feedback electrode **31** can likewise be embodied in strip-type fashion and be arranged between the body zones **12** of two adjacent strip-type transistor cells. In this case, a feedback electrode **31** can be assigned to each of the transistor cells. In this case, transistor cells and feedback electrodes **31** are arranged alongside one another alternately in the drift zone **11**, in the manner as illustrated by dashed lines in FIG. **7**. Furthermore there is also the possibility of assigning feedback electrodes **31** only to individual transistor cells from among the transistor cells, wherein the ratio $k=n_R/n_T$ between the number n_R of feedback electrodes **31** and the number n_T of transistor cells is less than 1 if the transistor cells and the feedback electrodes have an identical geometry. Thus, there is the possibility, for example, of assigning a feedback electrode **31** only to every n-th (where $n>1$) transistor cell, such that $k=1/n$ holds true. Furthermore, the feedback electrodes can also be arranged in a manner distributed as desired, for a given ratio of $k<1$. Thus, by way of example, transistor cells and feedback electrodes can alternate in some regions, while a plurality of transistor cells are arranged directly adjacent to one another in other regions.

It should be noted that a transistor cell in connection with the present description should be understood to mean an arrangement including a body zone, a source zone and a gate electrode—or a gate electrode section—which has a continuous body zone or whose body zone is delimited toward all sides in the semiconductor body by the drift zone **11** of the compensation zone **14**.

The compensation zones **14** arranged below the body zones **12** can be embodied in strip-type fashion in a manner corresponding to the geometry of the body zones **12**, as is illustrated for a transistor cell in the left-hand part of FIG. **7**. Furthermore, the compensation zones **14** can also have a geometry that deviates from the geometry of the body zone **12**. Thus, by way of example, a plurality of pillar-type compensation zone **14** can be arranged below a strip-type body zone **12** as is illustrated for a transistor cell in the right-hand part of FIG. **7**. In this case, the pillars can have any desired geometry with regard to their perimeter and can be e.g., square (as illustrated), oval, circular, hexagonal, or polygonal in any desired fashion.

Optionally, more highly doped drift zone sections **16** (not illustrated in FIG. **7**) are present below the feedback electrodes **31**. These more highly doped drift zone sections can be in strip form in a manner corresponding to the geometry of the feedback electrodes **31** but can also have a geometry that deviates from the geometry of the feedback electrode **31**. Thus, by way of example, there is the possibility of providing a plurality of pillar-type more highly doped drift zone sections below a strip-type feedback electrode **32**. In this case, the pillars can have any desired geometry with regard to their parameter and can be e.g., square (as illustrated), oval, circular, hexagonal, or polygonal in any desired fashion.

In the case of the component illustrated in FIG. **7**, the transistor cells and the feedback electrodes **31** have an identical geometry, namely a strip-type geometry in the example. However, the geometry of the transistor cells and the geometry of the feedback electrodes can be chosen independently of one another. Referring to FIG. **8**, which illustrates a further example of a MOS transistor on the basis of a horizontal cross section through a semiconductor body **100**, there is the possibility, for example, of realizing the transistor cells as strip-type transistor cells in accordance with the example explained with reference to FIG. **7**, but of realizing the feedback electrodes **31** as pillar-type electrodes having a rectangular, round or oval cross section. In this case, a number of such pillar-type feedback electrodes **31** can be assigned to each transistor cell, as is illustrated using solid and dashed liens in FIG. **8**. Furthermore, there is also the possibility of assigning such pillar-type feedback electrodes **31** only to some of the transistors cells, as is illustrated on the basis of solid lines for the feedback electrodes **31** in FIG. **8**. Thus, by way of example, in accordance with the example explained above with reference to FIG. **7***b*, there is the possibility of assigning a number of feedback electrodes **31** only to every n-th (where n>1) transistor cell.

In a manner not illustrated in more specific detail, it is possible to provide compensation zones **14** below the body zones **12** and more highly doped drift zone sections **11'** below the feedback electrodes **31**. These compensations zones **14** and more highly doped drift zone sections **11'** can be realized, for example, in strip form or in pillar form.

In the case of the component illustrated in FIG. **8**, the feedback capacitance Cgd can be set by way of the number of pillar-type feedback electrodes **31**. In this case, the feedback electrodes can be distributed as desired among drift zone sections arranged between the transistor cells. In this case, the number of feedback electrodes **31** can be set by way of the number of drift zone sections in which feedback electrodes are realized, and can furthermore be set by way of the mutual distance between the feedback electrodes **31**. It holds true here that the feedback capacitance Cgd is all the higher, the more drift zone sections with feedback electrodes are present and the smaller the distance between the individual feedback electrodes.

FIG. **9** illustrates an example of a MOS transistor in which a plurality of pillar-type feedback electrodes are assigned to each transistor cell **12**, that is to say in which pillar-type feedback electrodes **31** are arranged in each drift zone section between two adjacent body zones **12**. In this case, the feedback capacitance Cgd is set by way of the number of feedback electrodes that are respectively assigned to a transistor cell, or by way of the mutual distance between the feedback electrodes **31**. As already explained, more highly doped drift zone sections **11'** can be arranged below the feedback electrodes **31**. The more highly doped drift zone sections can have a pillar-type geometry, as is illustrated in the left-hand part of FIG. **9**, wherein in those regions in which no feedback electrode is arranged, the more highly doped drift zone sections **11'** can reach the front side of the semiconductor body. The more highly doped drift zone sections **11'** can also be realized in strip-type fashion, as is illustrated in the right-hand part of FIG. **9**. In this case, the more highly doped drift zone sections **11'** reach between the pillar-type feedback electrodes **31** to the level of the feedback electrodes **31** or as far as the front side **101** of the semiconductor body.

FIG. **10** illustrates a further example of a MOS transistor on the basis of a horizontal cross section through a semiconductor body **100**. In the case of this transistor, the individual transistor cells have a rectangular geometry, that is to say that the body zones **12**—and accordingly the source zones **13** (not illustrated)—are rectangular, especially square, in this component. It should be noted that such a rectangular geometry of the body zones **12** was chosen merely for explanation purposes. It goes without saying that the body zones **12** can also have any other geometry, and be for example circular, hexagonal or polygonal in any desired fashion. In the case of the MOS transistor illustrated in FIG. **10**, the feedback electrodes **31** are pillar-type feedback electrodes having a rectangular, in one embodiment square, cross section in the example illustrated. It goes without saying that these pillar-type feedback electrodes **31** in accordance with FIG. **10** and also the pillar-type feedback electrodes in accordance with examples 8 and 9 explained above can also have a different cross section and be realized for example as circular or oval pillars or pillars having any desired polygonal geometry. In this case, a feedback electrode **31** can be assigned to each of the transistor cells. The transistor cells, on the one hand, and the feedback electrodes, on the other hand, are in this case arranged respectively in grid-type fashion, wherein the grids with the transistor cells and the grid with the feedback electrodes are arranged offset with respect to one another. The number of transistor cells corresponds to the number of feedback electrodes if a feedback electrode is assigned to each transistor cell. Furthermore, there is also the possibility of setting a ratio $k=n_R/n_T$ between the number n_R of feedback electrodes **31** and the number n_T of transistor cells such that it is less than 1. In this case, the feedback electrodes **31** can be arranged in a manner distributed as desired between the transistor cells in the drift zone **11**.

FIG. **11** illustrates an example of a MOS transistor. In the case of this transistor, the transistor cells have a rectangular geometry, but can of course also have a circular geometry, a hexagonal geometry or a geometry that is polygonal in any desired fashion. The feedback electrodes **31** are realized as strip-type electrodes in the case of this component. In this case, transistor cells and strip-type feedback electrodes can be arranged alternately in a direction of the transistor cell grid. Furthermore, there is also the possibility of distributing the feedback electrodes **31** such that a feedback electrode **31** is arranged, for example, only in every n-th interspace between adjacent transistor cells, as is illustrated on the basis of solid lines in FIG. **11**. For a ratio $k=n_R/n_T$ between the number n_R of feedback electrodes **31** and the number n_T of transistor cells less than 1, the feedback electrodes **31** can also be arranged in a manner distributed as desired between the transistor cells in the drift zone **11**.

In the exemplary embodiments in accordance with FIGS. **10** and **11**, more highly doped drift zone sections **11'** can be provided below the feedback electrodes in a manner not illustrated in more specific detail. These more highly doped drift zone sections **11'** can have a pillar-type geometry or else a strip-type geometry,

FIG. **12** illustrates a further embodiment of a MOS transistor on the basis of a horizontal cross section through a semiconductor **100**. FIG. **12** illustrates the semiconductor body of this MOS transistor in the edge region. The edge region is that region of the semiconductor body **100** which is adjacent to an edge **105** of the semiconductor body **100** in a lateral direction. In the case of this component, it is provided that although the transistor cells or the body zones of the transistor cells **12** extend as far as the edge region **106**, the feedback electrodes **31** are arranged at a distance from the edge region **106**, that is to say do not extend in a lateral direction of the semiconductor body as far toward the edge region **106** towards the body zones **12**. In the example illustrated in FIG. **12**, the transistor cells and the feedback electrodes have a strip-type geometry. It goes without saying that other geometries from among the geometries explained above can also be provided for the transistor cells and the feedback electrodes.

In a further variant it is provided that the feedback electrodes extend closer to the edge region **106** of the semiconductor body than the transistor cells, the transistor cells in this case being realized such that the transistor cells arranged closest to the edge region have no source zones, that is to say are modified transistor cells.

A method for producing the trenches for the feedback electrodes is explained below with reference to FIGS. **13**A to **13**D. These figures illustrate this method on the basis of vertical cross sections through the semiconductor body **100** during different method processes. In this case, the figures illustrate the semiconductor body only in the region of the later drift zone **11**.

Referring to FIG. **13**A, the starting point is formed by providing the semiconductor body **100**, in which a doped semiconductor zone of the first conduction type is adjacent to the front side **101**, the semiconductor zone forming the later drift zone **11**. Complementarily doped semiconductor zones **14'** can be present in the semiconductor zone, and extend in a vertical direction of the semiconductor body **100** and form the later compensation zones **14**. Optionally, doped semiconductor zones **16'** which are of the first conduction type but are doped more highly than the later drift zone are present at a distance from the semiconductor zones **14'** or adjacent to the semiconductor zones **14'** (not illustrated). The semiconductor zones **16'** likewise extend in a vertical direction of the semiconductor body **100** and form the later more highly doped drift zone sections **16** of the semiconductor component. The section of the semiconductor body with the semiconductor zones **14'**, **16'** which is adjacent to the front side **101** of the semiconductor body **100** is an epitaxial layer, for example, in which the doped semiconductor zones **14'**, **16'** can be produced as early as during the epitaxial growth. The semiconductor zones **14'**, **16'** can—as illustrated—reach as far as the front side **101**, but can also end at a distance from the front side in a vertical direction.

Referring to FIG. **13**B, trenches **106** are produced in the semiconductor body **100** during further method processes, which trenches extend into the semiconductor body in a vertical direction proceeding from the front side **101** and form the basis for the trenches of the later feedback electrodes. The trenches **106** can be produced by sufficiently known method processes, such as, for example, by an etching method using an etching mask (not illustrated) which leaves the front side **101** free in sections in the regions in which the trenches **106** are intended to be produced.

If doped regions **16'** of the first conduction type are present, then the trenches can be produced in one embodiment in such a way that the trenches are arranged above these doped regions **16'**, such that a part of these doped regions **16'** is removed by the production of the trenches.

Referring to FIG. **13**C, in further method processes, an oxide layer **50'** is produced on the front side **101** and in the trenches **106**. The oxide layer **50'** is produced by thermal oxidation, for example, and can have a thickness such that it completely fills the trenches **106**. In this case, the thickness of the oxide layer **50'** is greater than half the trench width of the trenches **106**. The thickness of the oxide can also be thinner than half the trench width. In this case, a residual trench (not illustrated) still remains after the production of the oxide layer. By using a thermal oxidation for producing the oxide layer **50'**, near the surface semiconductor material of the semiconductor body **100** is converted into an oxide under the influence of oxygen and temperature. This oxidation has the effect, inter alia, that edges of the trenches **106** are rounded, to be precise not only edges within the trenches **106** but also edges at the transition to the front side **101**. The temperature during the oxidation additionally gives rise to (desirable) out-diffusion of dopant atoms from the semiconductor zone **14'** doped complementarily with respect to the drift zone **11** and from the further doped semiconductor zones **16'** optionally present, thereby giving rise to the compensation zones **14** and more highly doped sections **16** of the drift zone **11** as explained in connection with the previous figures.

Rounding of the edges of the trenches **106** in which the feedback electrodes **31** subsequently arise is desirable insofar as owing to the geometry of the trenches, the later feedback electrode **31** does not have any sharp edges either. As a result, it is possible to avoid field spikes in the region of the feedback electrode if a reverse voltage is present at the finished component during operation.

Referring to FIG. **13**D, the oxide layer **50'** is removed from the front side **101** and from the trenches **106** in the region of the later transistor cell array, but remains on the front side **101** in the region of an edge **107** of the semiconductor body **100**. The remaining section of the oxide layer **50** forms a passivation layer in the edge region of the later component. In addition to this passivation layer, conventional edge termination structures such as e.g., field rings or VLD zones (not illustrated) can also be provided in the edge region. The removal of the oxide layer **50'** in the region of the later transistor cell array is effected, for example, by using a masked etching method using an etching mask that covers the edge regions of the semiconductor body **100**.

After the production of the trenches for the feedback electrodes, it is possible to carry out customary method processes for producing the transistor cell array, thus resulting overall in the component structure explained with reference to FIG. **1**, with the difference that the feedback electrode **31** in FIG. **1** is illustrated schematically as a rectangular electrode in cross section, while a feedback electrode with rounded corners results during the production of a transistor cell array on the basis of the component structure illustrated with reference to FIG. **13**D.

Method processes for producing the transistor cell array include for example: producing a dielectric layer on the front side **101** and in the trenches **106**, which forms the gate dielectric **22** and the feedback dielectric **32**; producing an electrode layer on the dielectric layer, to be precise above the front side **101** and in the trenches, which forms the gate electrode **21** and the feedback electrode **31**; producing contact holes in the electrode layer and the dielectric layer above the compensation zones **14**, which reach as far as or into the semiconductor body **100**; implanting or diffusing dopant atoms of the second conduction type via the contact holes into the semiconductor body **100** in order to produce the body zones **12**; implanting or diffusing dopant atoms of the first conduction type via the contact holes into the semiconductor body **100** in order to produce the source zones **13**; producing a further electrode layer, which is insulated from the first electrode layer by a further dielectric layer and which forms the source electrode **41**.

Before the source electrode **41** is produced, the contact holes can be extended further into the semiconductor body **100**, such that the source electrode **41**, as illustrated in FIG. **1**, makes contact with the source zones **13** and the body zones **12**. The first electrode layer, which forms the gate electrodes **21** and the feedback electrodes **31**, can be realized in such a way that it completely fills the trenches, such that the feedback electrodes **31**—as illustrated in FIG. **1**—completely fill the trench. In a manner not illustrated in more specific detail, there is also the possibility of producing the feedback electrodes **31** in such a way that they are only arranged in the region of the sidewalls and bottom of the trench. A region of the trench which remains after the production of the feedback electrode **31** is then filled with a dielectric layer. Referring to FIG. **1**, that is the dielectric layer which is arranged between the gate electrode **21** or feedback electrode **31** and the source electrode **41** and which is designated by the reference symbol **23**.

Finally, it should be pointed out that features which were explained above in connection with just one example can be combined with features of other examples even if this was not explicitly mentioned. Thus, in one embodiment, features of the claims specified below can be combined with one another as desired.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

The invention claimed is:

1. A method for producing a MOS transistor having a feedback electrode arranged in a trench, comprising:
- providing a semiconductor body having a first side, a transistor cell array region and an edge region;
- producing a trench extending into the semiconductor body proceeding from the first side;
- producing an oxide layer on the first side and in the trench by thermal oxidation;
- removing the oxide layer from the trench and from the first side in the transistor cell array region and maintaining the oxide layer in the edge region;
- producing a dielectric layer on the first side and in the trench;
- producing an electrode layer on the dielectric layer; and
- producing a body zone,
- wherein the trench is produced distant to the body zone in a lateral direction of the semiconductor body.

2. The method of claim **1**, wherein the electrode layer completely fills the trench.

3. The method of claim **1**, wherein the dielectric layer forms a feedback dielectric and a gate dielectric.

4. The method of claim **1**, wherein the electrode layer forms at least in part a gate electrode and the feedback electrode.

5. The method of claim **1**, wherein the semiconductor body has an inner region and an edge region, wherein the trenches are produced in the inner region, and wherein the oxide layer remains in the edge region.

6. A MOS transistor comprising:
- a drift zone of a first conduction type;
- at least one transistor cell having a body zone, a source zone separated from the drift zone by the body zone, and a gate electrode, arranged adjacent to the body zone and dielectrically insulated from the body zone by a gate dielectric;
- at least one compensation zone of a second conduction type arranged in the drift zone; and
- at least one feedback electrode arranged at a distance from the body zone in a lateral direction of a semiconductor body, in which the body zone, the source zone, and the drift zone are arranged, the at least one feedback electrode dielectrically insulated from the drift zone by a feedback dielectric and electrically conductively connected to the gate electrode,
- wherein a section of the drift zone is present between the body zone and the feedback dielectric in the lateral direction of the semiconductor body.

7. A MOS transistor comprising:
- a drift zone of a first conduction type;
- at least one transistor cell having a body zone, a source zone separated from the drift zone by the body zone, and a gate electrode, arranged adjacent to the body zone and dielectrically insulated from the body zone by a gate dielectric;
- at least one compensation zone of a second conduction type arranged in the drift zone;
- at least one feedback electrode arranged at a distance from the body zone in a lateral direction of a semiconductor body, in which the body zone, the source zone, and the drift zone are arranged, the at least one feedback electrode dielectrically insulated from the drift zone by a feedback dielectric and electrically conductively connected to the gate electrode; and
- a plurality of transistor cells arranged at a distance from one another,
- wherein a section of the drift zone is present between the body zone and the feedback dielectric in the lateral direction of the semiconductor body.

8. A MOS transistor comprising:
- a drift zone of a first conduction type;
- at least one transistor cell having a body zone, a source zone separated from the drift zone by the body zone, and a gate electrode, arranged adjacent to the body zone and dielectrically insulated from the body zone by a gate dielectric;
- at least one compensation zone of a second conduction type arranged in the drift zone; and
- at least one feedback electrode arranged at a distance from the body zone in a lateral direction of a semiconductor body, in which the body zone, the source zone, and the drift zone are arranged, the at least one feedback electrode dielectrically insulated from the drift zone by a feedback dielectric and electrically conductively connected to the gate electrode,
- wherein the feedback dielectric together with the gate dielectric forms a continuous dielectric layer, and
- wherein a section of the drift zone is present between the body zone and the feedback dielectric in the lateral direction of the semiconductor body.

9. A MOS transistor comprising:
- a drift zone of a first conduction type;

at least one transistor cell having a body zone, a source zone separated from the drift zone by the body zone, and a gate electrode, arranged adjacent to the body zone and dielectrically insulated from the body zone by a gate dielectric;

at least one compensation zone of a second conduction type arranged in the drift zone;

at least one feedback electrode arranged at a distance from the body zone in a lateral direction of a semiconductor body, in which the body zone, the source zone, and the drift zone are arranged, the at least one feedback electrode dielectrically insulated from the drift zone by a feedback dielectric and electrically conductively connected to the gate electrode; and

a plurality of transistor cells arranged at a distance from one another,

wherein the feedback dielectric together with the gate dielectric forms a continuous dielectric layer, and

wherein a section of the drift zone is present between the body zone and the feedback dielectric in the lateral direction of the semiconductor body.

10. The method of claim **1**, wherein producing the oxide layer comprises producing the oxide layer such that the trench is filled by the oxide layer.

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